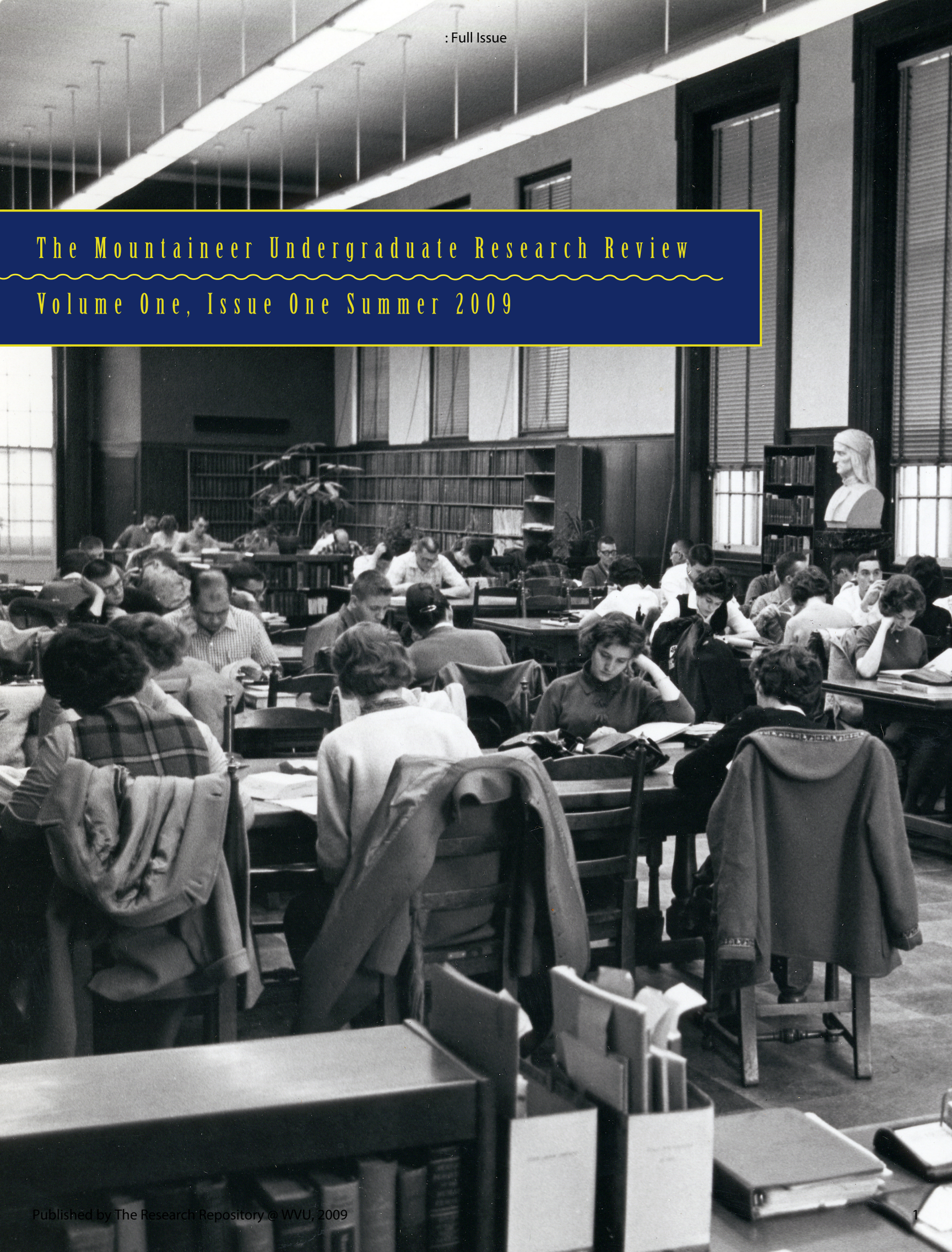
Volume 1 Article 1

June 2009

Full Issue

Mountaineer Undergraduate Research Review



The Mountaineer Undergraduate Research Review

Volume One, Issue One Summer 2009

THE MOUNTAINEER UNDERGRADUATE RESEARCH REVIEW

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VOLUME ONE, ISSUE ONE

WEST VIRGINIA UNIVERSITY
HONORS COLLEGE

MORGANTOWN, WEST VIRGINIA

The *Mountaineer Undergraduate Research Review* (*MURR*) publishes outstanding research performed by undergraduates at West Virginia University. *MURR* is a publication of West Virginia University Honors College, and is sponsored by West Virginia Experimental Program to Stimulate Competitive Research (WV EPSCoR). *MURR* is published on the Honors College website (www.honors.wvu.edu). Papers are reviewed by qualified faculty members at WVU, and are reviewed and edited by a Student Editorial Board.

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ACKNOWLEDGEMENTS

James Siekmeier, SilverMoon, Lloyd Carroll, John Lamb, Brian Woerner, Greg Dick, Jonathan Boyd, Justin Legleiter, D. J. Pisano, Kimberly Barnes, Cynthia Chalupa, Karen Anderson, and Stan Hileman.

Special thanks to the West Virginia Higher Education Policy Commission, in particular Dr. Paul Hill, Vice Chancellor of Science and Research, and Dr. Jan Taylor.

The *Mountaineer Undergraduate Research Review* is sponsored by the National Science Foundation's Experimental Program to Stimulate Competitive Research.

THE HONORS COLLEGE AWARDS FOR EXCEPTIONAL INQUIRIES

The editors are pleased to announce the recipients of the inaugural Honors College Awards for Exceptional Inquiries.

The winners are chosen with a rating system based on professorial review and consideration of the editors.

Receiving the Honors College Award for Exceptional Inquiries into the Humanities is Joseph Schaeffer with his paper "Vergangenheitsbewältigung and the Danzig Trilogy."

Receiving the Honors College Award for Exceptional Scientific Inquiries is Adam Sadowski with his paper "Biomimetic Promotion and Inhibition of Crystal Growth in Calcium Carbonate."

The Editors of MURR

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A LOOK AT NEOLIBERALISM IN BOLIVIA: THE WATER WAR TO THE PRESENT

Matthew Clements

In April of 2000, in the city of Cochabamba, Bolivia, mass protests over the privatization of water resources shook the very fabric of Bolivian society and politics. Behind this revolt that has come to be known as the Water War lays an omnipresent obstacle to Bolivia's stability and development: neoliberalism. Neoliberalism is an economic model that came about in the 1980's and sought to deregulate state run economies and open the market up to foreign investment (Dangl 2007, 25). According to Benjamin Dangl (2007, 7), the author of *The Price of Fire*, "Bolivia has been a longtime lab rat for neoliberalism, an economic system that promised increased freedoms, better standards of living and economic prosperity, but in many cases resulted in increased poverty and weakened public services." Neoliberalsim, in combination with weak democratic institutions, became a catalyst for the events that unfolded in the past decade in Bolivia. To better understand the effects of neoliberalism, it is important to investigate the causes and results of the Water War as one of the most vital case studies of neoliberal policies and the effect weak democratic institutions had on the political culture in Bolivia. The Water War, which virtually took over the city of Cochabamba, not only changed the politics of water distribution but also set the stage for future demonstrations and the democratic revolution that would change the political system in Bolivia and force a greater level of government accountability to the people.

Bolivia has a long history with the privatization of industry that certainly predates the events that took place in Cochabamba in 2000. John Perkins, a self-proclaimed "economic hit man" and author of two books on international economic deceit, declares that in the 1970s, "Bolivia was ripe for privatization" (Perkins 2007, 95). It was near this time frame that Bolivia instituted one of the IMF's first Structural Adjustment Programs (SAP) (Perkins 2007, 96). Perkins claims that Bolivia's elite class "had a long history of yielding to and prospering from foreign mining companies; they had incurred excessive debts; and, feeling vulnerable to neighboring countries, their traditional enemies, as well as to their own indigenous populations, they desired to secure Washington's promise of protection, and grow rich in the process" (Perkins 2007,

96). This is evident in the 1980's, when the vast mines of the Bolivian countryside, as well as large reserves of petroleum, were privatized (Lewis and Olivera 2004, 14). Later, in 1994, Bolivian President Gonzalo Sanchez de Lozada passed the Law of Capitalization, which privatized telephone services, airlines, and the railways, weakening Bolivia's Gross Domestic Product as profits became outsourced to wealthy multinational corporations (Dangl 2007, 120). While these newly privatized industries became less responsible to the growing economic concerns including unemployment and low tax revenues, the Bolivian public was never able to truly influence national politics and end the injustice served by policies of privatization.

Opening the door for the policies of neoliberalism has been the weak history of democracy in Bolivia in which democratic rule did not justly represent the people of Bolivia. Since independence in 1825, Bolivia has seen varying forms of democratic and military rule with nearly 200 coups in nearly 200 years of independence. Following a democratic revolution in 1952, coups in 1964 and 1971 installed military regimes, and it wasn't until 1985 that democracy finally returned to Bolivia (BBC News). In a country that changes political leaders on a constant basis and has only practiced democracy for the past twenty-four years, democratic institutions such as the legislative, executive, and judicial branches are, and faith in these institutions is, weak. In her writing of *Democratic Consolidation in Latin America?*, Jennifer Holmes assesses the "democratic health" of several Latin American nations including Bolivia (Holmes, Millett and Perez 2008, 5). She finds that Bolivia is one of the most corrupt nations in Latin America and that Bolivia also exhibits low levels of political rights and civil liberties (Holmes, Millett and Perez 2008, 12). Her use of varying statistics also indicates that only 59% of Bolivians feel there is a need for democracy in order to develop, 62% support a democratic government, and only 39% of Bolivians support their form of democracy (Holmes, Millett and Perez 2008, 12). These numbers show the dissatisfaction and lack of faith Bolivians have with democratic governance, as well as the poor state of democratic governance that is in place in Bolivia. Holmes also tackles development and economic concerns in Latin America, finding that Bolivia's Gross Domestic Product of $4,400 is one of the lowest in Latin America and that there is a large gap between the nation's wealthy and poor (Holmes, Millett and Perez 2008, 15). Using this data, it is easy to conclude that Bolivia's system of governance is corrupt, ineffective, and largely distrusted by the Bolivian populace. This inefficient governance and the lack of faith in elected officials have been important in recent events in Bolivia because these aspects have factored into Bolivia's adherence to demands from international organizations and the United States to implement neoliberal reforms in order to develop.

It wasn't until 1999, when the World Bank and International Development Bank issued reports regarding the privatization of water making it a pre-condition for receiving development loans, that politics began to change (Dangl 2007, 59). As Oscar Olivera, one of the organizers of the Water War and the author of *Cochabamba! Water War in Bolivia* points out, the Bolivian

populace could not possibly have handled a major increase in service rates that would have accompanied the privatization of water due to the low wages that most Bolivians make (Lewis and Olivera 2004, 8). The Bolivian government, under the leadership of Hugo Banzer, quickly set out to appease the international lenders and create policies that could allow for the privatization of key economic sectors. The result was Law 2029, passed in October of 1999, which attempted to govern drinking water and sanitation (Dangl 2007, 59). This law greatly changed the regulation of water that was in place at the time as water to rural regions was cut off, small neighborhood water systems were made illegal, private wells were put under the jurisdiction of the owner of the water distribution system, and collecting rain water was prohibited (Lewis and Olivera 2004, 9).

Law 2029 set the stage for a 40 year contract with an international consortium of water companies known as *Aguas del Tunari* over the exclusive rights to the water system in Cochabamba (Lewis and Olivera 2004, 9). This law, which superseded any national law, was given to a questionable multinational corporation that was eventually tied to a holding company of the U.S. corporation Bechtel (Dangl 2007, 61). This contract also specified that the rates would increase based on the consumer price index in the United States, a standard most Bolivians could never have possibly met (Lewis and Olivera 2004, 10). Once the contract was in effect, prices skyrocketed, even as running water was only available for around two hours a day (Lewis and Olivera 2004, 10).

In response, several Bolivians began to organize a political opposition to the privatization of water. The local workers union, *Fabriles*, joined with a group called *Pueblo en Marche* (*People on the Move*) and another group called *CODEAC* (*Committee in Defense of Water and the Family Economy*) to form a new movement known as the *Coordinadora de Defensa del Agua y la Vida* (*Coalition in Defense of Water and Life*), or simply the *Coordinadora* (Lewis and Olivera 2004, 27). Initial meetings mainly concerned peasants who felt neglected by the current policies, but over time, as the populace became angered by the new contract with *Aguas del Tunari*, the popularity and influence of the *Coordinadora* grew (Lewis and Olivera 2004, 30). Mobilizations such as roadblocks and workers strikes took place in the winter months of 1999-2000, and the government decided to hold talks with the opposition (Lewis and Olivera 2004, 31). The result of the talks was a three month grace period in which the government was to attempt to meet the demands of the opposition for cheaper and fairer water distribution (Lewis and Olivera 2004, 32).

Even after this initial agreement was reached, the opposition planned a peaceful demonstration to take place in Cochabamba on February 4, 2000 to prove that the fight was not over, yet not intended to provoke violence (Dangl 2007, 64). Instead, the protests turned ugly for three days as the police from the capitol city, La Paz, fought against many Bolivians who took to the streets and formed blockades until a peace agreement was reached (Lewis and Olivera 2004, 36).

From this point, it became evident to the parties involved that the government was not placing pressure on *Aguas del Tunari*, who was also failing to meet the demands of the opposition (Lewis and Olivera 2004, 37). As the initial date set for meeting the demands of the protesters, April 4, came closer, a new consensus was made by the opposition that it wasn't sufficient to simply have demands met, but rather *Aguas del Tunari* needed to be kicked out of Bolivia for failing to even attempt to fix the problems that it had caused (Lewis and Olivera 2004, 37).

So, on April 4, the opposition set up roadblocks and worker strikes in Cochabamba in protest of the current situation (Dangl 2007, 65). This time, the national police from La Paz was not mobilized and the army did not intervene, leaving the opposition alone on the streets (Lewis and Olivera 2004, 37). Tens of thousands of civilians mobilized and demanded change, threatening to take over the local offices of *Aguas del Tunari* (Lewis and Olivera 2004, 40). The security forces began to let their presence be known while shooting at rural protesters and firing tear gas into crowds in the urban areas of Cochabamba (Dangly 2007, 66). The scene grew more violent as hundreds were injured in conflict in the city, and there was the tragic death of a 17-year old pedestrian at the hands of a U.S. trained sniper (Dangl 2007, 66). As the leaders of the opposition attempted to negotiate with the government, they were arrested for treason, only further infuriating the protesters who refused to go home (Lewis and Olivera 2004, 42). Eventually, on April 10, negotiations were revived due to pressure on both the government and the opposition to end the riots taking place within the city. In the end, after hours of tedious negotiations, the *Coordinadoa* was given the role of overseer of the formation of a municipal-run water system that would attempt to be more efficient and less costly and the contract with *Aguas del Tunari* was terminated (Lewis and Olivera 2004, 46). The Water War was over.

The political ramifications of this conflict have been widespread. As far as the water distribution in Cochabamba, the violence was over, a new government-run company known as *SEMAPA* (*Municipal Services for Potable Water in Cochabamba*) took over the water distribution, rates dropped, the efficiency of water systems was slightly increased, and the political tensions decreased. This being said, the transition to a public run company has not been a smooth one, as there are still problems in service efficiency due to a lack of funding (Dangl 2007, 68). As for Bechtel, the corporation that was ultimately kicked out of Cochabamba, it filed a $50 million lawsuit to recover losses incurred by Bolivia's cancellation of the water contract but dropped the charges after international pressure was applied (Dangl 2007, 68).

The Water War not only solved these issues, but it represented a shift in the beliefs of the people. Near the conclusion of the Water War, one pedestrian asked Oscar Olivera, one of the primary leaders of the Coordinadora, "What have we really gained?" (Lewis and Olivera 2004, 48). The answer to this question is a complex one. Yes, the Cochabambinos had gained the right to drinking water, but other social problems such as poverty, unemployment and corruption re-

mained present. The answer to this question seems to be that the real gain of the Water War came in a less tangible form. The Bolivian people, through their political will, changed the rules of governance, forcing an increased level of government accountability. No longer would elected officials be able to create policies without the fear of public backlash that could destabilize the political system. Before the war, neoliberal policies had been present and the people may have been upset by unfair practices, but the people had yet to shake the foundations of privatization and force political powers to recognize the will of the people. Now, the precedent was set for the people to be heard and to force the change of policies that were inefficient and potentially harmful towards a majority of Bolivian people.

For a while, tensions were put to a rest and a new president, Gonzalo Sanchez de Lozada (Goni), took office in 2002. Opposition movements to neoliberal policies had gained substantial support, as is evident in the 2002 presidential election in which indigenous leader and former cocalero, Evo Morales, finished a close second to Goni in a runoff election (Sidorenko). Evo, an advocate for the end of neoliberal policies, was a participant in the Water War and his second place finish showed that anti-neoliberal policies had gained considerable support. It was in the early months of 2003 that tensions ran high and the precedent of popular protests seen in the Water War would be influential in national politics once again. It was February 11 when protests broke out between a striking police force and the national army in the Presidential Palace in La Paz (Lewis and Olivera 2004, 168). The protests were directed at an IMF policy that called for an increased income tax in order to create greater state revenue and decrease a large budget deficit held by the federal government (Dangl 2007, 77). The police force was already striking, demanding higher wages to deal with inflation, when the tax was formally announced. There are varying accounts as to what really happened, but it is believed that students from the region, angry at the new tax, began throwing rocks into the Presidential Palace with support from the police, who were bunkered down in their barracks on the other side of the Presidential Plaza (Dangl 2007, 85). In response, the army fired tear gas into the police barracks, and chaos ensued (Dangl 2007, 85). For the next two days, there was constant gunfire near the Plaza that ended with thirty one dead, forcing the president, Goni, to rescind the tax and appease the Bolivian populace (Lewis and Olivera 2004, 169).

This time, tensions did not die down so easily. It was several months later, on September 19, 2003, that the Gas War broke out (Dangl 2007, 118). The conflict took place nationwide, but broke out, once again, in the city of Cochabamba over the proposed plan to export gas at low rates to foreign countries and corporations (Lewis and Olivera 2004, 170). This policy caused a great deal of dissatisfaction to the Bolivian people, who see their large gas reserves as their ticket to development, and the demand for nationalization intensified (Dangl 2007, 118). Over the next few weeks, protests were rampant and conflict between the government and the populace was everywhere. The conflict culminated a month later in the city of El Alto, on the outskirts of La

Paz, where a near civil war broke out (Dangl 2007, 131). After days of conflict, blockades, and protests, the president, Goni, was forced to resign due to demands of the protesters nationwide and a lack of political support from the elites (Lewis and Olivera 2004, 170). In the end, 67 Bolivians had died in the Gas War and the tensions remained high. Vice President Carlos Mesa took office with the promise of his resignation calming the protests temporarily.

At first glance, it appears that the conflicts over the IMF tax and the Gas War were isolated incidents regarding different policies imposed on Bolivians. The reality of the situation seems that while the Water War, the IMF conflict, and the Gas War are separate, they are connected by the precedent that was set during the Water War, in which the people themselves had forced the government to change some sort of neoliberal policy. In both the Water War and Gas War, the policy was regarding privatization of key sectors of Bolivian industry, and the IMF conflict regarded the policy of increasing taxes to reduce deficits. It certainly is possible that without the precedent of the Water War, conflict would have eventually erupted, but the Water War laid the framework for a people's revolution against what they saw to be unjust policies. It was only after the Water War that the people understood exactly how to disrupt government politics and gained the confidence that their voices would be heard.

The struggle was not over, as President Carlos Mesa had yet to give up power and there was great uncertainty regarding the future of Bolivian politics and life. In the later months of 2003 leading into 2004, President Mesa attempted to rule and solve the issues regarding gas exportation, but he eventually resigned due to pressures for him to leave office (BBC News). In his place, Supreme Court Justice Eduardo Rodriguez took the office of the President, until new elections could be held as was required by the constitution in such circumstances (BBC News). At this point, there was a great uncertainty in politics, but as elections came closer, the people had the opportunity to select the leader they felt would guide them out of chaos and end the political revolution. In the new elections, Evo Morales, the populist leader, ran against U.S. educated Jorge Quiroga, amongst several other candidates (Saavedra). To no surprise, Mr. Morales won the election under a socialist platform that promised to govern for the benefit of the masses (Saavedra). The people had done all they could. Popular unrest had forced the government's hand and mandated a democratic transition to a new government that had promised to fix the wrongs that neoliberalism had helped to create in the past.

This election signified the completion of a revolution that was years in the making and was part of a change in public opinion across Latin America. According to a PBS Frontline report, "Since 2000, leftist candidates have swept into power in two-thirds of Latin America's countries" (Talbot). Jim Shultz, executive director of Democracy Center, states, "The bottom line is that Latin America is in open rebellion of the economic policies of the Washington consensus… Sometimes it happens in the ballot box. Sometimes it happens on the street, like in Bolivia. It is,

in essence, the same rebellion" (Talbot). Mr. Shultz brings up an excellent point when he states that this rebellion other the movements across Latin America, are rooted in the economic policies of the Washington consensus. The Center for International Development at Harvard University claims, "The phrase 'Washington Consensus' is today a very popular and often pilloried term in debates about trade and development. It is often seen as synonymous with 'neoliberalism'" (Center for International Development at Harvard University). It has become a trend not only in Bolivia that neoliberal policies continue to create a greater economic divide and force the majority of citizens to find new ways, and leaders, to gain a voice in politics.

As it is seen in Bolivia, the democratic transition was rooted in policies of inequality and exploitation; the policies of neoliberalism. When the policies of neoliberalism were combined with the weak and untrustworthy democratic institutions in place, the Bolivian people decided to take action to change the politics that they saw as being ineffective. These policies created enough economic disparity and exploitation that the people became disgusted by what they saw in the governments that they had put in power. In fact, the percent of Bolivians living under one U.S. dollar a day had shown a steady increase throughout the 1990's and into the turn of the new millennium (Index Mundi). When initial complaints and protests were ignored by leaders who were supposed to be accountable to the people and failed to cause change, the people needed to find new ways to alter policy. It was at this point, when the initial attempts at reform had failed, that the people had no other choice than to demand change using drastic measures. These circumstances necessitated an incident to draw the government's attention - an incident like the Water War.

While it may seem that the Water War was a single, isolated incident, further examination reveals that it was the policies of neoliberalism in combination with the weak and unrepresentative set of democratic institutions in place in Bolivia that had built up pressure on the people to fight their way out of the economic hardships that a large proportion of the Bolivian population faced. It was the past privatization of airlines, railways, mines and petroleum that made the people realize they needed to draw the line and not allow their government, which had grown irresponsible to the desires of the populace, to give away water, a resource many Bolivians saw as a natural right. This is a view backed by scholar Marta Lagos, who claims, "The meaning of democracy (in Latin America) comprises three elements: The demand for liberty; the power of elections; and the right to satisfaction of basic needs" (Lagos 2008). This quote shows that water, a basic need for survival, is seen in Bolivia and across Latin America as a part of democracy that is guaranteed to the people and cannot be taken away because doing so would be considered a social injustice.

Today, the effects of the Water War can be seen in many indirect forms. As one may suspect, street protests, blockades, and popular marches are very prevalent in Bolivian society.

From all the major cities of La Paz, Santa Cruz, and Cochabamba to all of the smaller urban areas of Oruro, Potosi, and Sucre, Bolivians continue to mobilize. In Bolivia, it seems the people have a unique definition and understanding of what democracy is. In previous years, democracy seemed to function as it does in the United States, where the people elect representatives and put faith in the judgment of these elected officials. Years of dissatisfaction over policies, like neoliberalism and privatization, built up anger and dissatisfaction among Bolivians, resulting in the revolution that ousted Gonzalo Sanchez de Lozada. For the people, the transition is not over and they continue to place pressure on the government by means of popular demonstrations. The Bolivian people, after years of failure, have little faith in the government institutions and, as a result, have taken a much more active voice in governing and developing the nation. It may not have been the Water War that generated this culture of protest, but it was the Water War that gave the people the confidence in the collective voice that has been used to insinuate change and foment a revolution.

While some may feel the revolution is not over, the people have done all they can in forcing change and electing Evo Morales, a leader who promises to do all he can to help Bolivia. Mr. Morales, who ran under a socialist platform promising to address various social problems, has changed politics in Bolivia since taking office in 2005. There is a feeling that while not all agree with how Evo approaches certain policies, he is attempting to help most Bolivians. He has taken steps to end neoliberal policies in Bolivia, going so far as to say, "The pillaging of our resources by transnational companies is over. From this day forward, all hydrocarbons in the country are nationalized" (Dvoskin). He has also been influential in drafting a new constitution and fighting against coca eradication, a policy endorsed by the United States. Evo, who was involved in the Water War, has been the most tangible result of the popular revolution that gained momentum in the spring of 2000, but only time will tell if he can solve the nation's plethora of problems.

As we have seen, the Cochabamba Water War, rooted in the policies of neoliberalism and privatization, in culmination with an existing set of weak governance, has changed Bolivia's political culture. A long history of privatization and economic exploitation had taken its toll on Bolivia and the privatization of water was the spark that ignited a revolution. Once the Water War took place, the framework for a popular revolution was laid and a struggle between the people and the government ensued. Only time will tell if Evo Morales, who holds the hopes and desires of the Bolivian people in his hands, will be able to change policies for the betterment of Bolivia. In the end, the Water War not only changed policies regarding water, but it also helped create a culture of popular struggle against an oppressive government, leading to conflict with the IMF, the Gas War, and the election of Evo Morales.

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VERGANGENHEITSBEWÄLTIGUNG AND THE DANZIG TRILOGY

Joseph Schaeffer

With the end of the Second World War in 1945, Germany was forced to examine and come to terms with its National Socialist era. It was a particularly difficult task. Many Germans, even those who had suspected the National Socialist crimes, were shocked by the true barbarity of the Nazi regime. Günter Grass, who spent 1945 in an American POW camp listening to the Nuremberg Trials, was one of those Germans. How could the Holocaust have arisen from the land of poets and philosophers?

German authors began to seek the answer to this question immediately following the end of WWII, and this pursuit naturally led to several different genres of German post-war literature. Some authors adopted the style of *Kahlschlag* (clear cutting), in which precise use of language would free German from the propaganda-laden connotations of Goebbel's National Socialist Germany. Others spoke of a *Stunde Null* (Zero Hour), a new beginning without reflection upon the past. These styles are easily recognizable in the works of early post-war authors like Alfred Andersch, Günter Eich, and Wolfgang Borchert. However, it would take ten years before German authors adopted the style of *Vergangenheitsbewältigung*, an analysis and overcoming of Germany's past.[1]

In 1961 Walter Jens wrote that only works written after 1952 should be considered part of the genre of German post-war literature (cited in Cunliffe 3). Without a distanced analysis of the Second World War an author would be unable to produce a true work of art. This claim is the logical, although more optimistic, successor to Theodor Adorno's famous quote (1951): "After Auschwitz, to write poetry is barbaric" (Adorno 30 Transl. mine.). Günter Grass proved with his Danzig Trilogy—*The Tin Drum* (1959), *Cat and Mouse* (1961), and *Dog Years* (1963)—that authors' works could overcome Nazism. In contrast to earlier post-war authors, Grass advocated an exact and honest treatment of Germany's National Socialist past.[2] His books formed a strong criticism of the forgetfulness of the Federal Republic of Germany (FRG or West Germany). Grass said: "It

had to do with the acceptance or denial of truth in a country which, defeated and divided, was burdened with the guilt of genocide and nevertheless, or perhaps consequently, was prepared to suppress, to render without context, everything which would raise the specter of the past and prevent the escape into the future" (cited in Malchow and Shafi 58 Transl. mine). In defiance of this German forgetfulness, Grass created barbaric, absurd, and grotesque scenes in order to integrate the crimes of National Socialism into his works.

The Danzig Trilogy constitutes an attempt at a socio-political and individual *Vergangenheitsbewältigung*. Grass' primary concern was to compel the discussion of National Socialist crimes in German post-war society. The Danzig Trilogy was remarkably successful at facilitating this socio-political *Vergangenheitsbewältigung*, with the three novels selling millions of copies and sparking a spirited debate in German society. However, Grass' novels also attempted to introduce an individual *Vergangenheitsbewältigung*. After WWII, most Germans differentiated between the fanatical National Socialist core (i.e., Hitler, Goering, Goebbels, and Himmler) and the larger German populace. Grass rejects this attempt to distinguish between "guilty" and "innocent" Germans. He not only criticizes a populace which overlooked or condoned German crimes, but suggests that the dual traits of guilt and innocence/suffering/victimization are bound together in human nature. Indeed, Grass suggests that the protagonists of the three novels—Oskar Matzerath, Heini Pilenz, and Walter Matern—suffer precisely because of their unwillingness to admit their own guilt. Individual *Vergangenheitsbewältigung* thus not only requires admittance of one's own role in socio-political crimes, but also the deeper recognition of man's innate capacity for evil.[3]

While it is not possible to fully examine the Danzig Trilogy in this short space, this article will nevertheless attempt to examine the main themes of each novel with respect to *Vergangenheitsbewältigung*. Grass's absurd and grotesque imagery alludes to the cult of National Socialism and the inhumanity of the Nazi era. In *The Tin Drum*, Oskar Matzerath is a perverted messiah who exposes societal immorality in some instances while taking the role of a dwarf Jesus in others. Oskar is both a prophet and a tempter. Mahlke, the protagonist in *Cat and Mouse*, is conversely a pious Catholic whose enlistment in the Germany Army symbolizes the Church's ineffective resistance of National Socialism. *Dog Years* changes the Trilogy's emphasis to the victims of Nazism. Both Eddi Amsel, a half-Jewish boy, and Jenny Brunies, a Roma orphan, suffer under the racism of the Nazi era. Together, the three novels constitute three different approaches to the theme of National Socialism and World War II.

In so far as each narrator in the Danzig Trilogy is consumed by their past, the Trilogy can be understood as a clear attempt at *Vergangenheitsbewältigung*. At the end of *The Tin Drum* Oskar Matzerath reflects upon his sins and the National Socialist perversion of the state. *Cat and Mouse* begins with an allusion to this perversion, as Heini Pilenz recalls how he once set a kitten—

claws out—upon Mahlke's neck. Mahlke, who disappears after the war, becomes symbolic of victimhood and personal responsibility. Finally, *Dog Years*, whose three narrators reflect upon their lives in Danzig-Langfuhr, alludes to the effect that National Socialist persecutions had on minorities.

The Tin Drum (1959)

The Tin Drum, which appeared in 1959, not only began the Danzig Trilogy but Günter Grass's literary career. Perhaps unsurprisingly, there are noticeable parallels between the novel and Grass' biography. Like Oskar, Grass was born in Danzig-Langfuhr to the community grocer. During the 1930s he became a member of the Hitler Youth and was later drafted into the Waffen SS. After his release from an American POW camp, Grass moved—like Oskar—to Düsseldorf, where he initially supported himself as a trader on the black market, a stonemason, and a sculptor.[4] Grass also performed as a drummer in a jazz band ("Günter Grass"). Despite similarities to Grass' life, *The Tin Drum* is not an autobiographical work. Rather, it is influenced by his personal experiences under the Nazi regime.

The Tin Drum's retrospective character is apparent from the novel's first page. Oskar Matzerath, the book's narrator, claims: "I start long before me; for no one should describe his own life who cannot summon the patience to consider at least half of his grandparents' before turning to his own existence" (12 Translation mine).[5] The novel's narrative, which spans several generations, alludes to the importance of one's predecessors. Although Oskar, with only a few exceptions, proceeds linearly, his story repeatedly returns to descriptions of his family.

Vergangenheitsbewältigung does not indicate a biographical work, but rather an understanding of the individual past and the societal past. Oskar fulfills this role. Particularly during his narrative after World War II, Oskar tells not only his story but that of the entire German state. With themes of guilt, innocence, petite bourgeoisie life, violence, and music, Oskar paints the rise of National Socialism. Indeed, in so far as these themes intersect in Oskar's own person, Oskar can be understood to symbolize German society before and after the National Socialist regime.

The question of guilt is inseparable from the larger theme of *Vergangenheitsbewältigung*. One of the most difficult and important questions of German post-war society was that of German guilt as opposed to National Socialist guilt. Was only Hitler guilty? Or the voluntary National Socialists? Or the entire German people? In *The Tin Drum*, Grass created a narrator who, despite (or perhaps as a result of) his childlike appearance, recognized the guilt of the entire

German people. Nevertheless, Oskar is a "patient in a sanitarium," a fact which he admits in his very first sentence (9). As the reader continuously confronts the absurdity of Oskar's narrative, he must remind himself that Oskar has been institutionalized. Oskar cannot always be trusted, an insight that becomes ever more apparent during the course of the book. Grass uses Oskar's unreliability to create a larger symbolic understanding of his story. The narrative, with its corrections and admissions of half-truths, mirrors that of a German post-war society which minimized or dismissed its connection to National Socialism.[6] Like German society, Oskar had to force himself—and occasionally was forced by his attendant Bruno—to admit the truth. Oskar's narrative is namely as unreliable as that of those Germans who suddenly became members of the inner resistance after the war.

Despite his presence during several immoral acts, Oskar is usually the unnoticed observer. Oskar spends his entire childhood as the silent partner to his mother Agnes's incestuous affair with her Polish cousin Jan. Agnes's German husband Alfred completes the love triangle and pretends to know nothing of his wife's affair. Only the Jewish toy merchant Sigismund Markus, who watches Oskar during Agnes and Jan's weekly meetings, knows everything. With remarkable foresight, he begs Agnes to end her affair and settle upon her German husband so as to protect herself during the coming war. Agnes pays Sigismund Markus no attention, but when she became pregnant with Jan's child in 1934, she becomes distraught, choosing to end both her life and that of her unborn child. In one of the most grotesque chapters in the novel, Oskar describes how his mother incessantly eats fish, eel, and sardines until she dies of fish poisoning. Her pregnancy drove her to suicide, responsibility for which Oskar later took upon himself. "The Gnome drummed her into the grave. Because of Oskar she no longer wanted to live; he killed her!" (219). Oskar exaggerated. Agnes, a Kashubian woman, was driven to suicide by her Polish and German lovers.[7] This foreshadowing alludes to the coming war between Germany and Poland, a war in which Danzig stood in the middle (Brodsky and Shafi 54).

Oskar's role in his second cousin Jan's death is much clearer. On September 9, 1939, Oskar travels to Jan's workplace, the Polish post office, where he hopes that the caretaker can repair his damaged tin drum. On his way he meets Jan, who had abandoned the post office's defence against the Germans to his colleagues. Forced to accompany Oskar back to the post office, Jan becomes embroiled in the opening battle of World War II. Particularly interesting is how Oskar, who by 1939 is 15-years old, exhibits a childlike yearning for a working drum. This endangers both Jan and the caretaker Kobyella, but Oskar's mania forms a stark contrast to Jan's cowardice. Grass wanted neither the Germans, symbolized by Oskar's manic search for the tin drum, nor the Poles, symbolized by Jan's cowardice in the face of attack, to be understood as heroes. Oskar first describes a completely innocent separation from his cousin Jan after the German capture of the Polish post office but later says that he would have to "stay close to the truth" (318). He admits that "[he] and Jan had barely left the letter room before … [he] placed himself between

two fatherly looking national guardsmen … and pointed to Jan, his father, with accusatory gestures which made the innocent into the guilty [one] who had brought an innocent child into the Polish post office" (318).[8] Oskar's guilt in Jan's betrayal is foremost an individual guilt—his opportunism mirrors that of those Germans who used Nazi racial laws to enrich themselves or settle grudges against their neighbors. However, Oskar's accusation of his Polish cousin/father symbolizes the German state's attempt to attribute the first shots of WWII to Poland. By admitting the underlying falsehoods of these accusations, Oskar—as a symbol for the German people—attempts both a personal and socio-political *Vergangenheitsbewältigung*.

Six years later, Oskar is responsible for the death of his other putative father, Alfred Matzerath. After a six year German occupation, the Matzerath family hides in its cellar and waits for the arriving Russian army. Only as the family hears the Russians descending the basement stairs does Alfred remember the Nazi party pin on his collar. He lets it fall to the ground, but Oskar gives it back to him immediately. Panicking, Matzerath sees no alternative but to swallow the party pin. It sticks in his throat, though, and the choking grocer is shot by an entering Russian soldier. Only later does Oskar admit his role in Alfred's death. "It wasn't quite true that the needle of the party pin was already exposed as I picked the treat [party pin] up from the concrete. The needle was opened only after I picked it up" (531-32).

Oskar's patricide is often evinced as part of an argument for his ultimate immorality. However, Oskar's betrayal is also interesting with respect to Vergangenheitsbewältigung. Oskar is, above all, an opportunist who betrays his fathers without consideration for their nationalities. As the National Socialists gained power, Oskar portrayed himself as a hostage before the German national guardsmen and betrayed his cousin/father Jan. Only six years later, Oskar betrays Alfred, a Nazi party member, to the advancing Russians. The parallels to the opportunistic betrayal of German Jews by their friends and neighbors are unmistakable.

Oskar's glass shattering voice, betrayals, and blasphemous desires contrast his childlike appearance. Grass stands the entire concept of childlike innocence on its head by asking if it is even possible during the Nazi era. The oft-quoted sentence—"I belonged to the clairvoyant infants, whose mental development was completed at birth and thereafter had only to express itself"—points to an early omniscience with its accompanying responsibilities (52). Oskar's clairvoyance imparted special responsibilities, since as a clairvoyant he had the ability to foresee the consequences of the National Socialist regime. One the one hand, Oskar symbolizes the Weimar Republic, which overlooked or minimized the danger of Hitler and the National Socialists despite clear warning signs in the form of the SA, the 1923 Munich Putsch, and *Mein Kampf*. On the other hand, Oskar symbolizes German individuals who supported the National Socialists despite (or as a result of) their racist and violent ideology. Oskar's childlike innocence belies his innate capacity for evil. As the priest asked during his baptism, "Do you reject Satan? And all his

works? And all his pageantry?" Oskar's godfather Jan Bronski agreed before Oskar could shake his head in disagreement (174). Oskar appeared awakened by Satanic influences and asked Satan as they left the church: "Were you able to endure everything?" Satan responded: "Did you see the church windows, Oskar? Everything is glass, everything is glass!" (174). By contrasting Oskar's clairvoyance (i.e., a moral lens) with his decision for Satan, symbolizing power and wealth, Grass alludes to German society's decision for the Nazi Party despite the accompanying consequences.

Grass uses the blasphemous discussion between Oskar and Satan during the baptism to satirize the youth cult of the National Socialists. Hitler, the young single Führer, and the Hitler Youth symbolized a vital, powerful, and growing Reich. Oskar symbolizes the true National Socialism. "Oskar may be a freak, but the world in which he lives is freakish. In other words, he represents an entire society which has become freakish" (Brockmann and Shafi 202). Grass contrasts Oskar—the small, disabled, permanent three year old—with the National Socialists who compared themselves to the vital and powerful youth. Like Oskar, who despite his maturity continued to play the part of the three year old, National Socialism was a perverted and grotesque movement. When Oskar shatters glass with his voice, acts as an accessory to theft, and leads the Stäuber youth gang, he contradicts society's conception of the innocent childhood. Grass uses the contrast between Oskar's intellectual maturity/clairvoyance and his childlike appearance to reject the concept of the innocent childhood.

Oskar's childlike appearance not only symbolizes the Nazi era, but a grotesque crippled FRG society which had prematurely ceased denazification (Brockmann and Shafi 208). Grass belonged to a society which attempted to classify former Nazis using black and white criteria when it made the attempt at all. The FRG recognized only a small, fanatical National Socialist core, which had misled or coerced the rest of German society. Others claimed to have been part of Germany's inner emigration.[9] How else could such barbarity have occurred in the country of "poets and thinkers"? Grass rejects this myth. Most of his characters, like the Matzeraths, belong to the petite bourgeoisie and were neither misled nor coerced. Alfred Matzerath entered the party in 1934, hung a picture of Hitler on his wall, and increasingly reprimanded his Polish relatives. Others, like the grocer Albrecht Greff and the alcoholic trumpeter Meyn, became party members as well. Even when the men explained their party membership in terms of friendship and brotherhood, they were well aware of Nazism's larger goals. When Maria calls Alfred a "premature ejaculator," he says that she could have easily "caught herself a foreign worker, the Frenchman who brings the beer" (376). With his insult, Matzerath indicates an awareness of the exploitation of foreign workers. Such instances lead Oskar to laugh at the Germans who claim to have been part of the inner emigration. "One speaks of the spirit of resistance, of the resistance groups. One is even supposed to have been able to internalize their emigration, which one calls: inner emigration. Completely ignorant of the Bible thumping, noble men fined by the

anti-aircraft defense during the war for improperly blacking out their bedroom windows and who now call themselves resistance fighters" (157).

While Grass's satirization of the petite bourgeoisie is not readily apparent, his thematic use of music—particularly with Oskar's tin drum—is more recognizable. Oskar is a drummer, and when Oskar is without his drum he loses part of himself.[10] Oskar's drum imparts special abilities. He becomes omniscient and is able to conjure the missing aspects of his story with the help of his drum. Like the *Wunderbille* (miracle glasses) from Brauxel & Co. in *Dog Years*, Oskar's drum acts as a mirror into the German past. It is precisely this ability which brings Oskar fame and fortune. First in the bar *Onion Cellar* and later on stage, Oskar enables a return into the past. As such, Oskar's drum becomes a physical instrument of *Vergangenheitsbewältigung*.

Grass uses music to draw a distinction between National Socialist culture and German culture. As early as 1934, Oskar draws spectators away from the National Socialist stage by playing a waltz on his drum. The typically German, refined waltz is to be understood as the antithesis of National Socialist culture. The trumpeter Meyn provides an additional contrast. As a drunkard, Meyn plays beautifully. As a sober party member, however, his once exceptional playing becomes merely average. After the war, Oskar writes: "There was once a musician who was named Meyn, and if he has not passed away, he still lives and plays trumpet beautifully" (264). Despite National Socialism's claims on German art and music, Grass exposes its incompatibility with true beauty. In the 1979 film adaption of *The Tin Drum* by Volker Schlöndorff (with Grass as an adviser), Oskar's drumming and singing in the service of the National Socialists are dark, violent, and dissonant.

The Tin Drum also alludes to the violence of National Socialism. Although the trumpeter Meyn "performed with considerable bravery during the night from November 9th to 10th, which one later called the Night of Broken Glass," he is forced out of the SA for killing his four kittens.[11] The juxtaposition of the SA's response to Meyn's brutality—praising violence toward the Jews and condemning animal cruelty—is one of the most absurd aspects of the entire novel. Without explicitly referencing the Holocaust, Grass alludes to the grotesque valuation of Jewish life. This passage reminds the reader of the ever present and perverted violence of the National Socialist era, a time in which Jews were worth less than animals. Grass shows how these perverted values affected the entire German society. As a young boy, neighborhood children parallel the actions of the SA men, cooking a piss soup and forcibly feeding it to Oskar.

National Socialist violence and German complicity is best expressed in Grass' powerful description of *Kristallnacht*, or the Night of Broken Glass. Oskar, whose Jewish toy merchant Sigismund Markus kills himself during the night, accompanies his father Alfred into the city center and observes the SA men taking pleasure in their destruction. Only Oskar seems to recognize

the true implications of *Kristallnacht*. "An entire gullible people believed in Father Christmas. But Father Christmas was really the Gas Man. I believe that it smells of nuts and almonds. But in truth it smelled of gas" (244). This passage is particularly grotesque. Without explicitly mentioning the Holocaust, Grass reminds his readers of the camps' most common execution method. By connecting almonds—a favorite Christmas treat—to the death camps, Grass's reader smells the execution as well as visualizing it. How can one eat roasted almonds again without thinking of the victims of National Socialism? Grass also has strong criticism for a German society which had believed in "Father Christmas." Germany desired power so strongly that it had placed its fortune in the hands of a barbaric, perverted Führer.

Cat and Mouse (1961)

While *Cat and Mouse* was published in 1961 as the second book in the Danzig Trilogy – between *The Tin Drum* and *Dog Years* – Grass originally envisioned it as part of the much longer *Dog Years* (Reddick xi). However, the story of Joachim Mahlke, narrated by Heinrich Pilenz, was too multifaceted to merely serve as a secondary storyline. *Cat and Mouse* is characterized by themes of responsibility, sexuality, religion, and militarism which force the reader to confront Germany's National Socialist past.

Cat and Mouse begins with an unexpected event in the style of the classic German *Novelle*.[12] Pilenz writes: "….and one time, when Mahlke was already able to swim…" (5). As he completes his tale, it becomes clear that, like *The Tin Drum*, *Cat and Mouse* is concerned with *Vergangenheitsbewältigung*. Pilenz continues: "in any event, it [the cat] jumped onto Mahlke's throat; or one of us grabbed the cat and placed it upon Mahlke's neck; or I … seized the cat and showed it Mahlke's mouse" (6). Like Oskar, Pilenz admits his guilt only after equivocation. Along with many other Germans, he had set the cat (symbolizing the National Socialist state) upon his friend's mouse (symbolizing the victim). At the time, Pilenz cared little that Mahlke suffered "only insignificant scratches" (6). Only later does Pilenz develop feelings of guilt and responsibility which drive him to write. "I, who showed your mouse to one and every cat, must now write" (6).

Responsibility is a multifaceted theme in *Cat and Mouse*. Pilenz, whose search for his friend Mahlke continues unabated after 1959, constantly returns to the summer day of the *Cat and Mouse*. That day symbolizes Pilenz's first act of betrayal, a fact that he admits only with great difficulty. Pilenz also bears responsibility for failing to help his friend Mahlke after his desertion from the German military. Mahlke sought refuge with his friend—"I [Pilenz], however, wanted nothing to do with it" (162). Instead, Pilenz proposed that Mahlke hide in the minesweeper boat the boys had explored as youths and only reluctantly picked up supplies from Mahlke's home.

Grass also suggests that Pilenz hid the can opener Mahlke would have needed to open his supplies underground, thus making him Mahlke's murderer. As Pilenz addresses his own guilt many years later, he repeatedly comes across the question that many other Germans faced in the process of their own *Vergangenheitsbewältigung*. To what extent does cowardice—an unwillingness to act morally in opposition to an immoral state—impart guilt? Grass' answer is made definitively clear in his several descriptions of Pilenz's guilty conscience.

The perversion of Mahlke's religious faith also speaks to the lack of moral resistance to the National Socialist state. Mahlke, a pious Catholic, wears a Maria amulet around his neck and faithfully attends church. It is thus remarkable that Mahlke becomes a reliable German soldier despite his faith and earlier resistance. Perversely, Pilenz argues that Mahlke's sense of military duty was inspired by longing for the German Army's highest honor—the Iron Cross. As a student, Mahlke stole the Iron Cross of a visiting soldier, and since that moment he yearned for one of his own. As a soldier, Mahlke earned an Iron Cross, but his heroics were prompted by particularly blasphemous courage. Mahlke claimed that the Virgin Mary guided his shells toward the enemy tanks, instantly evoking an image of the German soldier penetrating the Virgin Mary. Ruhleder interprets Mahlke's story as the description of a perverse sexual union, writing: "He [Grass] casts doubt on Mahlke's calling and reveals the hero's sexual desire for the Virgin" (606).

Ruhleder alludes to the messianic descriptions of Mahlke in *Cat and Mouse*. Pilenz narrates in the beginning "that they threw [Mahlke] out of the *Jungvolk* and placed him in the Hitler Youth because he neglected to perform his duty on Several Sunday mornings and lead his troop – Mahlke was a *Jungvolk* leader – into the Jäschkentaler forest" (31). This was met with widespread amazement among Mahlke's classmates. Together with his piousness, such scenes lend him the qualities of a messianic or prophetic savior (Ruhleder). Mahlke's classmates recognized these traits in him. One day they drew a sketch of him on the chalkboard "and beyond his head and sufferer's face [was] a halo: the savior Mahlke was perfect and his image did not disappoint (46). Ruhleder claims: "Mahlke's is an abortive attempt at becoming the Saviour by having the narrator sponge his countenance off the blackboard" (604). His military enlistment and later resistance thus becomes a vital part of the *Novelle's* plot.

The reader is led to understand that Mahlke's religious faith is subsumed and later replaced by his faith in the German state. It is his absurd longing for the Iron Cross that leads him to enlist in the German military, and Mahlke's messianic promise goes unfulfilled so that he might become a brave German soldier. National Socialism subsumed religious faith, as Mahlke chooses earthly fame over heavenly reward. Similarly, Grass describes a complicit church. Cat and Mouse depicts churches which served National Socialism rather than God, churches which turned away refugees and helped hide former Nazis. Grass thus forces churches to begin their

own *Vergangenheitsbewältigung* and ask how they could support the National Socialist state despite its atrocities.[13]

Mahlke left the military when it became clear that he would not be able to speak at his *Gymnasium*. He had been expelled following his theft and no honor, not even the Iron Cross, could change the headmaster's decision. Mahlke told Pilenz: "I've done my part, right? …Not that I'm afraid, simply had enough" (161). With Mahlke, Grass rejects the National Socialism conception of youth, which idealized young men as brave and bellicose. Even if he were neither a hero of the resistance nor a messiah, he did not belong to those who marched to their end on the front.

Mahlke's refuge in the sunken minesweeper thus draws parallels to the inner emigration of the Nazi era. He removed himself from the era's barbarity by choosing good over evil. While not completely innocent, Mahlke stands in contrast to those Germans who suddenly discovered the concept of inner emigration in Summer 1945. In light of Germany's defeat and massive war guilt, Mahlke's desertion appears particularly prescient. Mahlke's disappearance and Pilenz's search for his old friend allude to the same concern. When Grass wrote *Cat and Mouse*, he observed a grotesque, guilty German society which rejected a close analysis of its past. Like his narrator Pilenz, Grass used the written word to conjure the specter of the past in order to confront and overcome it.

Dog Years (1963)

The epic *Dog Years*, which was published in 1963, is the logical conclusion to *The Tin Drum* and *Cat and Mouse*. Characters from the earlier books occasionally appear, such as Tulla Pokriefke, Oskar Matzerath, Alfred Matzerath, Albrecht Greff, and Oswald Brunies.[14] It is thus logical that many of the same themes from the previous books are discussed in *Dog Years*, albeit in different manners. *Vergangenheitsbewältigung* becomes the novel's central theme, but guilt, violence, and persecution are also discussed.

While Grass alludes to *Vergangenheitsbewältigung* in *The Tin Drum* and *Cat and Mouse*, he makes it the driving theme in *Dog Years*. The protagonist Brauchsel or Brauxel or simply Amsel contracts two other narrators to tell the story, or more accurately, their version of his story.[15] Despite its three narrators, *Dog Years* can thus be understood as the story of a single man. Amsel's story begins far before World War II as he accompanies a friend, Walter Matern, on a walk around the Weichsel River. Like all young boys, they enjoyed throwing stones in the water, but on that day not a single stone was to be found. Without the stone, "the pocketknife in Matern's hand

[became] warmer. Amsel had given it to him" (14). Matern threw Amsel's gift—a gift that had made the two boys blood brothers—into the water. This symbolic gesture foreshadows Matern's coming betrayal of his half-Jewish friend Amsel. Decades later, the scene is repeated as Amsel alias Goldmäulchen (Goldenmouth), dredges the entire Weichsel River to find the pocketknife and return it to Matern. As expected, Matern is unable to resist throwing it back into the water. While Grass uses the first throw to foreshadow betrayal, the second alludes to the difficulty of *Vergangenheitsbewältigung*. Matern's attempts to make amends for his past become fruitless and laughable as he repeats his original act of betrayal.

Walter Matern's guilt is exceptional. While it's true that he was an SA member, so were many other Germans. What separates him from the other SA men is his betrayal and beating of Eddi Amsel, the friend he used to protect as a boy. As the SA men encircled Amsel, it was Matern who threw the first blow. It was Matern who punched out Amsel's teeth. After the war, however, Matern remembers events differently. Unemployed and burdened with guilt and shame, he finds himself in the Cologne train station, which his description transforms into a secular church. While using the restroom, Matern finds the names and addresses of his accomplices on the bathroom wall and begins to plot revenge against those who harmed his friend. This scene is absurd on two levels. First, Matern—who led the attack against Amsel—tasks himself with finding justice for his friend. Grass uses Matern to symbolize the guilty members of FRG society who, overlooking their own guilt, search it out in others. Second, Matern's revenge originates in a train station bathroom, a room intended for the lowest and most grotesque bodily functions. From the beginning, the plot is to be understood as absurd and immoral.

Insofar as Matern attempts to place blame for Amsel's attack upon his accomplices, he seeks to avoid admitting his own responsibility. His attempts at revenge most often take on a sexual nature, as he sleeps with the wives or daughters of his former friends. Matern's promiscuity leads to a gonorrheal infection, which makes his sexual "justice" all the more grotesque. Matern never truly achieves justice for Amsel, though. His visits to his former accomplices always take the form a perverted or immoral act, and his revenge goes unfulfilled.

Matern's attempts at revenge are absurd and grotesque. They also uniformly punish the innocent, such as women or children, rather than Matern's former accomplices. During a visit with the Leblich family, for example, Matern breaks a fountain pen—one of the children's Christmas presents—but later replaces it to assuage his conscience. Still consumed by revenge, he first considers raping Leblich's six year old daughter, but settles for killing Leblich's canary when the daughter proves unavailable. Another former friend was not so lucky; Matern slept with his teenage daughter during his visit. Despite having rejected National Socialism after the war, Matern's attempts at *Vergangenheitsbewältigung* merely provide his evil impulses with another avenue of expression.

Like the FRG society which he symbolizes, Matern's attempt at Vergangenheitsbewältigung is superficial, an attempt to relegate guilt to another party. However, "in the year 1955, as all of the children born in the peace year of 1945 [turned] 10, the *Wunderbrille* appeared from Brauxel & Co., preventing all attempts at secrecy" (595).[16] Brauxel & Co.'s Wunderbrille function as a fantastic, if absurd, polygraph which prevent all attempts at equivocation.[17]

Those glasses, which Brauxel & Co. sent to market in the hundreds of thousands, made parents transparent… Father and mother, moreover: each adult, as soon as he reached his thirtieth year – the glasses probed, recognized, and, even worse, disrobed them (598).

Matern's ability to deny his guilt is lost as soon as he buys his putative daughter Willi a pair of *Wunderbrille*.[18] After wearing the glasses, Willi instantly discovers Matern's guilt and his past crimes.

Matern is later threatened with the Wunderbrille in one of the most striking chapters of the Danzig Trilogy. Naively, he agrees to take part in a "Discussion with our [German] Past." The radio program begins with an absurd and perverted prayer: "O great Creator of the dynamic and ever applicable World Dialogue….stand by us, for we wish to fully discuss the readily approachable discussion topic of Walter Matern (628). The consequence of this discussion—or more aptly inquisition—is that Matern must admit that he killed a dog in an act of political resistance, that he later adopted Hitler's former dog, that he called his friend Amsel a kike, and that he beat Amsel on a fateful winter day.[19] This last admission came only when his interrogator, his putative daughter Willi, examines him through the *Wunderbrille*. Grass thus suggests that Germany's *Vergangenheitsbewältigung* cannot be voluntary but must rather be arrived at through interrogation by an innocent party. This foreshadows the conflict in the 1960s between the 1968 Generation and their parents over German crimes during National Socialism.

The origin of the *Wunderbrille* with Brauxel & Co. alludes to the role of the victim in *Vergangenheitsbewältigung*. Amsel suffered the most of all the characters in *Dog Years*, and he thus has the greatest interest in the admission of the truth. Indeed, Brauxel develops his *Wunderbrille* in response to the FRG's unwillingness to confront its National Socialist past. With his *Wunderbrille*, Brauxel becomes West Germany's collective conscience, and the one-time victim becomes his persecutors' judge.

As in *The Tin Drum*, Grass rejects the concept of youthful innocence. If Matern's guilty conscience reminds him of his past sins, Tulla Pokfriefke symbolizes the conscienceless, uniformly evil individual. Tulla bullies young Jenny Brunies because of her Roma heritage, packing her in snow and leaving her to freeze in the woods. Similarly, Tulla shuts Jenny and her cousin in a deep freeze warehouse. It is Tulla who reports Jenny's father Oswald Brunies to the police.

His crime? He longed for small candies—unavailable during wartime—and stole his students' vitamins as a replacement. Tulla also bullies Eddi Amsel because of his Jewish heritage, such as when she forbids him to sketch their family dog.

Tulla symbolizes the National Socialist woman. She longs for an Aryan pregnancy, reeks of bone dust, and steadfastly follows the race laws. Her barbaric character contradicts the ostensible innocence of women and of children. In the Danzig Trilogy, none of the Germans are innocent. Each is partially or wholly tinged with the stain of National Socialism.

The depictions of National Socialist violence are particularly grotesque. The attack on Eddi Amsel is described as follows: "Nine fists found a tenth face, which [Matern's] fist split in half. And as the nine fists tired, [Matern's] fist carried on. And as all the teeth were missing, [Matern] choked out a scream. And Kike Kike Kike was [Matern's] refrain" (665).[20] Jenny Brunies is attacked in a similar manner. The neighborhood children, led by Tulla Pokriefke, bury her in the snow, and Jenny lost her toes to frostbite as a result. Jenny's father Oswald was also a victim of National Socialism, placed in a concentration camp for his petty theft of vitamins from his school's supply.[21]

The concentration camps—the best known symbols of National Socialist crimes—are explicitly referenced for the first time in the Danzig Trilogy in *Dog Years*. In one of *Dog Years'* many subplots, Tulla Pokriefke's cousin, Harry Liebenau, is bothered by an unidentifiable smell in his army unit's camp. It would waft over from a nearby hill, which lay before a factory and a pair of railway tracks. The hill was later called Bone Hill, "its name since Harry's cousin Tulla spit the name in its direction" (403). Tulla's description was accurate. The bones of the dead concentration camp victims were deposited at Bone Hill, a fact of which the Danzig population was well aware. Grass implies that those who knew without acting share the burden of guilt. If one knows of a crime, yet does nothing to stop it, is one not also guilty? This is one of the central questions with which individual Germans had to contend after the war.

Persecution is also discussed in *Dog Years* as part of the greater theme of National Socialist violence. Eddi Amsel and Jenny and Oswald Brunies become victims of the National Socialist hysteria, each symbolizing a different persecuted group. Eddi—Jews; Jenny—Roma; and Oswald—political prisoners. Together with Albrecht Greff (homosexual) and Oskar Matzerath (disabled) in *The Tin Drum*, these characters symbolize National Socialism's victims.

Greff committed suicide and Oskar joined his persecutors on the National Socialist stage. In contrast to the passivity of *The Tin Drum*, the characters in *Dog Years* react actively. Oswald, who dies in the concentration camp, symbolizes the targeted internment of supposed enemies of the state. Although Oswald meets a negative end, Amsel and Jenny form positive responses

to their persecution in the form of inner and outer resistance. Jenny, a delicate ballerina, learns to turn her weakness into strength. Jenny comforts Harry when they find themselves locked into the deep freeze warehouse by Tulla. "Now, you mustn't freeze anymore, Harry. You know, I was once hidden inside a snowman. And as I was inside, I learned much" (349). This symbolic meaning of this passage is clear. Shut in the deep freeze warehouse (the National Socialist Reich) by an evil individual (Tulla or, symbolically, the Nazis), Jenny learns how to survive by calling upon her inner strength.

Amsel's resistance followed a different path. Jenny pulled back from society—she changed her appearance and moved to Berlin—but Amsel adopted an entirely new personality. After the attack, he left his home of Danzig-Langfuhr and took a new name. He replaced his broken smile with golden teeth, founded a successful business as a scarecrow producer, and became unrecognizable to his former friends and acquaintances. Only Harry Liebenau was able to see through Amsel's disguises. As Amsel, then Haseloff, returned to Danzig, Liebanau listed his many aliases: "I once knew someone, looked like you, was named something different…He first was named Steppuhn, then he was named Sperbella, then Sperlinski. Do you know him?" (387). Liebenau was in this respect unique. Even Matern, whose *Vergangenheitsbewältigung* centered on his attack upon Amsel, was unable to recognize his old friend.

Although Amsel's sudden transformation is absurd, it has symbolic importance. In contrast to his former persecutors, Amsel was able to overcome his attack and move on with his life. Amsel recognized the tragedy of his past and was nonetheless, or perhaps resultantly, able to become a successful businessman. Grass thus suggests that only the victims of National Socialism will be able to undergo a successful Vergangenheitsbewältigung. Matern, whose postwar existence is supposedly predicated on repentance, never admits his own guilt. When he speaks of the attack on Amsel, he neglects to count himself among the attackers. As a result of his purposeful omission, Matern remains an unfulfilled and detestable man, unable to recognize his former victim. Grass uses physical characteristics to highlight this contrast between attacker and victim. Amsel/Brauxel/Goldmäulchen is an eminent businessman while Matern—infected with gonorrhea—remains unemployed, homeless, and plagued by a persecution complex.

Rather than removing himself from society, Amsel blends in. As a young man, he was already known for his scarecrows, and he turns this into a business after the war. However, Amsel's scarecrows have a far different effect after the war than before. As a child before the war, Amsel's created anthropomorphic scarecrows which functioned as protection against the world which persecuted him. When Amsel clothed his scarecrows in SA uniforms, he transformed the National Socialist threat into the absurd. The SA men/scarecrows were only superficially threatening; underneath they were fully without substance.

Amsel's post-war scarecrows become even more frightening and grotesque. After his unsuccessful interview for the radio play, Matern flees east, to East Berlin. On his way, "Scarecrows —Don't look out the window!—pulled themselves up from their roots" (672). Through his scarecrows, Amsel becomes the persecutor, or more aptly, a representative of justice. Matern cowers before the scarecrows, which remind him of his past crimes. His fright only increases as he visits the scarecrow factory with Brauchsel. The two men ride deeper and deeper into the mine in which the factory is situated, a journey with close parallels to Dante's Inferno. Indeed, Brauchsel and Matern travel through multiple levels in the factory, each with its own hellish scarecrow. Matern immediately recognizes these parallels and continuously refers to the factory as "Hell." For Matern, the trip through the factory is a personal hell, and the reader can understand it as the culmination of Amsel's revenge.

Conclusion

The Danzig Trilogy is one of the most important works in German post-war literature. To paraphrase Walter Jens, Günter Grass created a new genre of German literature—*Vergangenheitsbewältigung*—with his first three books. Although earlier German authors had discussed German guilt, Grass was the first to discuss an all-encompassing guilt, which included even children. Grass wanted to lay bare the barbarity of National Socialism, and he used grotesque and absurd symbolism to this effect. When he wrote the trilogy, that was the only way in which one could describe such an immoral and perverted era. As a result, the Danzig Trilogy is a difficult work to read. Not only do the three books contain subtle symbolism, but German readers were forced to confront their country's National Socialist past. Grass passes judgment on an entire people, a people which let Hitler seize power and was silent during genocide. Grass does not admit the existence of innocent Germans, only those who were born after the war.

Grass' intended the Danzig Trilogy to be disconcerting and uncomfortable so as to challenge his readers. Oskar Matzerath, *The Tin Drum's narrator*, is a perverted gnome who not only bears responsibility for his fathers' deaths, but commits particularly violent and blasphemous acts. *Cat and Mouse* is the story of Joachim Mahlke, the once pious Catholic, who chooses the German army over the Catholic Church. Later, as he decides to desert, he is likely betrayed by his friend Heinrich Pilenz. *Dog Years* also treats the theme of betrayal. Eddi Amsel and Jenny Brunies, a Jew and a Roma, are betrayed by their friends during the Nazi era.

All three books have a close connection to the theme of *Vergangenheitsbewältigung*. Oskar Matzerath recognizes his guilt and spends his later years trying to understand his crimes and make amends. Heinrich Pilenz's unending search for Joachim Mahlke is also a form of *Vergan-*

genheitsbewältigung. So long as Mahlke remains missing, Pilenz continues to bear the guilt for his disappearance. The fates of the main characters in *Dog Years*—Matern and Amsel—is similarly connected. Until Matern admits his guilt in the attack on Amsel/Brauxel/Goldmäulchen, his old friend will remain hidden from him.

With his Danzig Trilogy, Grass alludes to the Germany's own incomplete *Vergangenheitsbewältigung*. His novels attempt to reveal National Socialist guilt and force its public discussion. The Danzig Trilogy was very successful in accomplishing this goal, resulting in an active discussion of German guilt. Even those Germans who denied their own sins could no longer ignore the past. Interestingly, Günter Grass admitted in his 2006 autobiography *Beim Häuten der Zwiebel* (*Peeling the Onion*) that he had been part of the Waffen SS rather than the Wehrmacht, as he had claimed for 51 years. Although Grass' strong criticism of former Nazis led many to brand him a hypocrite, it is worth noting how the weight of a Nazi past influenced the *Vergangenheitsbewältigung* of the man who invented the genre.

FOOTNOTES

1. *Vergangenheitsbewältigung*, a German term literally meaning "overcoming of the past," can refer to several different concepts. After WWII, Germany and Judaism struggled with reconciliation in light of German crimes during the Holocaust. Germany also had to accept its defeat by the Allies, which required a radical rethinking of German identity and strength. Finally, Germany had to admit its own guilt in WWII, particularly the mass extermination of millions of Jews, Roma, homosexuals, and disabled persons. When this paper makes use of the term *Vergangenheitsbewältigung*, it is to be understood according to this last concept.

2. It's true that earlier authors, such as Heinrich Böll, discussed National Socialism in their works, and the effect of short stories like "Traveler, are you coming to Spa…," "One time in Odessa," and "Outside before the door" is undeniable. However, these works primarily discuss how Germans were affected by the war. *Vergangenheitsbewältigung* differentiates itself from this earlier Trümmerliteratur (literally, "rubble literature") insofar as it treats the subject of German guilt. The differences between these two genres would be an interesting basis for further study.

3. Oskar Matzerath is the best representation of this simultaneous guilt and innocence in the Danzig Trilogy. The section on *The Tin Drum* will show how Oskar symbolizes the individual *Vergangenheitsbewältigung*. Oskar is not only guilty of his own individual crimes, but also displays knowledge of the larger socio-political crimes which characterized the National Socialist state. Interestingly, Grass' characters' capacity for both good and evil foreshadowed society's surprise at the Eichmann trial (1961) and the Milgram (1961) and Zimbardo (1971) experiments. Most members of the public were shocked that "normal" or "civilized" individuals were capable of such brutality.

4. The move from Danzig to Düsseldorf symbolizes another type of *Vergangenheitsbewältigung*—that which was precipitated by the loss of former German or culturally German territories following World War II.

5. Unless otherwise noted, all translations from the Danzig Trilogy are mine. If interested in reading the Danzig Trilogy in translation, the Ralph Manheim translations are excellent and quite faithful to the originals.

6. Grass finally admitted in 2006 that that he had been a member of the Waffen SS. The announcement coincided with the publication of his memoirs, *Beim Häuten der Zwiebel* (*Peeling the Onion)*, and was seen by many as a publicity stunt. As a result of Grass' long standing advocacy for openness about individuals' National Socialist past, many of his critics branded him a hypocrite.

7. The Kashubians are a Slavic ethnic group concentrated in north-central Poland.

8. In the original, Grass calls the national guardsmen *Heimwehrmänner*, literally meaning "men of the homeland defense." In the context of the attack on the Polish post office, they're best understood as German soldiers.

9. Many Germans claimed to have been part of the inner emigration or resistance after the war. These terms refer to a passive resistance in which Germans would reject National Socialism in their lives. While some Germans embraced the concept of inner emigration during the rise of Nazism and far before WWII, others did so opportunistically after 1945.

10. Oskar gives up his drum after the death of his father Alfred by symbolically throwing it into Alfred's grave. Immediately thereafter, he begins to cry, whereby Schugger Leo (an oddly prophetic former seminarian who attends each local funeral) exclaims: "Look at the Lord, how he grows, oh, how he grows!" (535). Leo's religious imagery is purposeful and alludes to an amazing change. Oskar develops a hunchback, which the reader is led to understand as a symbol of his guilt. More importantly, Oskar's negative traits disappear with the rejection of his drum. Only when he resumes drumming—and Oskar must be forcibly brought to this point—do these reappear. The reader is thus led to believe that the omniscience supplied by Oskar's drum is accompanied by the seduction of evil behavior.

11. The SA or *Sturmabteilung* (Assault Detachment) was the military wing of the National Socialist party.

12. The *Novelle* was a particularly popular style in the 19th century. In its classical form, it is characterized by a small group of characters, a rejection of character development (e.g., personality traits are static), a shocking event at the story's beginning, and a sudden, unexpected ending.

13. This is/was a particularly pertinent issue for the Catholic Church, as the Vatican was the first foreign government to recognize the new National Socialist regime in 1933.

14. Tulla first appears in *Cat and Mouse* as a foil to Mahlke's sexual modesty.

15. *Dog Years'* protagonist Eddi Amsel is known by many names. Brauchsel, Brauxel, Amsel, and Goldmäulchen (Goldenmouth) are only some of his aliases.

16. *Wunderbrille* can be translated in English as either *Wonder Glasses* or *Miracle Glasses*. I chose the term *Miracle Glasses*, which I used at the beginning of this paper, because I feel that it better conveys the absurdity in Grass's work.

17. Brauxel is another of Amsel's aliases.

18. Like Oskar in *The Tin Drum*, Willi Sawatzki, a supporting character, has two putative fa thers—her mother's husband and Matern.

19. In the German original, Matern calls Amsel Itzich, a pejorative for Jews. The term "kike" most closely conveys the intended venom of the term, although it is not a literal translation.

20. The German is very lyrical, and the beauty of the language contrasts strongly with the words' content. Rather than minimizing their effect, the lyricism draws the reader's attention to the barbarity of the attack.

21. The narrator, Heinrich Pilenz, insinuates that the Oswald was actually punished for his membership in the Free Masons and that the vitamins served as a cover.

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PHYSICAL & NATURAL SCIENCE

GBT RADIO MONITORING OF MAGNETARS

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Abstract

Magnetars are very exotic objects that are related to neutron stars and pulsars. A neutron star is formed when a massive star undergoes a supernova explosion. The super-dense core that is left after such an explosion is a neutron star. It is approximately 10 miles in diameter, yet weighs more than our Sun. We can observe some of those neutron stars as pulsars. Pulsars are highly magnetic, fast spinning neutron stars that emit beams of radio waves from their magnetic poles. Their high magnetic field and spin period are due to the conservation of magnetic flux and momentum during formation. Pulsar spin periods range from 1ms-8s and tend to slow down rapidly. That is another indication of a strong magnetic field, as magnetic braking causes the pulsar to spin-down rapidly. Magnetars are a type of a neutron star with extremely high magnetic fields of 1015-1014 G, which makes these stars the most magnetic objects known. These fields are thought to be generated by a dynamo action during the magnetar's formation (Duncan and Thompson 1992). This is known as a magnetar model. The decay of the magnetic field creates powerful X-ray or gamma-ray emission. However, this magnetic field decays rather fast which makes the magnetar's detectable lifespan short. Some of the known magnetars have poorly understood radio emission. Our group was motivated to better study the correlation between X-ray and radio activity of magnetars via a radio monitoring project. We are regularly observing eight magnetar sources that are visible with the 100-m Green Bank Telescope (GBT) located in Green Bank, WV. Our program is the first major effort to monitor these sources on a regular basis and complements other existing observing programs of southern objects at the Parkes radio telescope (Burgay et al. 2009; Camilo et al. 2009) as well as the high-energy monitoring projects with the Swift gamma-ray observatory and XMM X-ray observatory.

Scientific Background

The magnetar model is used to describe anomalous X-ray pulsars (AXPs) and soft-gamma repeaters (SGRs). AXPs are slowly rotating neutron stars with bright quiescent X-ray radiation and bursts. SGRs are characterized by high-luminosity bursts of soft gamma-ray emission. Currently, four SGRs and nine AXPs are known (for a recent review, see Woods and Thompson (2006)). The rotation periods of magnetars are in the range 2–12s. With the exception of 1E1547.0– 5408 where a periodicity was found in the radio, the periods are known through observation of pulsed X-ray and/or gamma-ray emission. Of particular interest is the magnetar XTE J1810–197. It was revealed in 2003 as the first AXP with transient emission when its luminosity increased 100-fold from the quiescent level (Ibrahim et al. 2004). Radio emission was subsequently detected using the Parkes telescope with period P = 5.54s (Camilo et al. 2006). This was in agreement with the X-ray period and indicated that magnetars are related to radio pulsars. Follow-up observations show this pulsar to be extremely luminous and have a virtually flat radio spectrum detectable up to frequencies of 144 GHz (Camilo et al. 2007a). The second radio emitting magnetar is 1E1547.0–5408, a variable X-ray source (Gelfand and Gaensler 2007) located in the center of supernova remnant G327.24–0.13. Although no X-ray pulsations were detected from this object, Parkes observations revealed a periodicity at P = 2.069s (Camilo et al. 2007b). The same position was previously observed during a Parkes multibeam Galactic plane survey in 1998, and no pulsations were found in the data. This suggests that in 1998 1E1547.0–5408 was fainter than in 2007. As for XTE J1810–197, it is not clear what the cause is for such changes in the electromagnetic activity of this object. This source has recently undergone an X-ray outburst in which pulsations were seen consistent with the radio ephemeris (Dib et al. 2008). While radio pulsations were not initially found (Camilo et al. 2009), more recent observations have shown that the radio emission has now returned (Burgay et al. 2009).

GBT Observations

As it is unclear what the relationship is between radio and high-energy activity in these sources, we became motivated to begin a monitoring program of all magnetars visible from the GBT. We were awarded time to observe AXPs and SGRs that are listed in Table 1 over the course of 8 epochs. The table lists all of our sources, their positions, periods determined from the X-ray pulsations, distance in kiloparsecs (1 parsec = 3.26 light years), and dispersion measure. The value of dispersion measure (DM) is very useful to us. It is related to the slowing down of lower frequency radio waves as they travel though the interstellar medium, much like the effect you get where visible light travels through a prism. With an electron density model of the galaxy and the DM of the sources, we can figure out the distance to our sources, which is what was done in

this case. The list of sources includes the original radio magnetar XTE1810−197 as a test source. An example observation is shown in Figure 1.

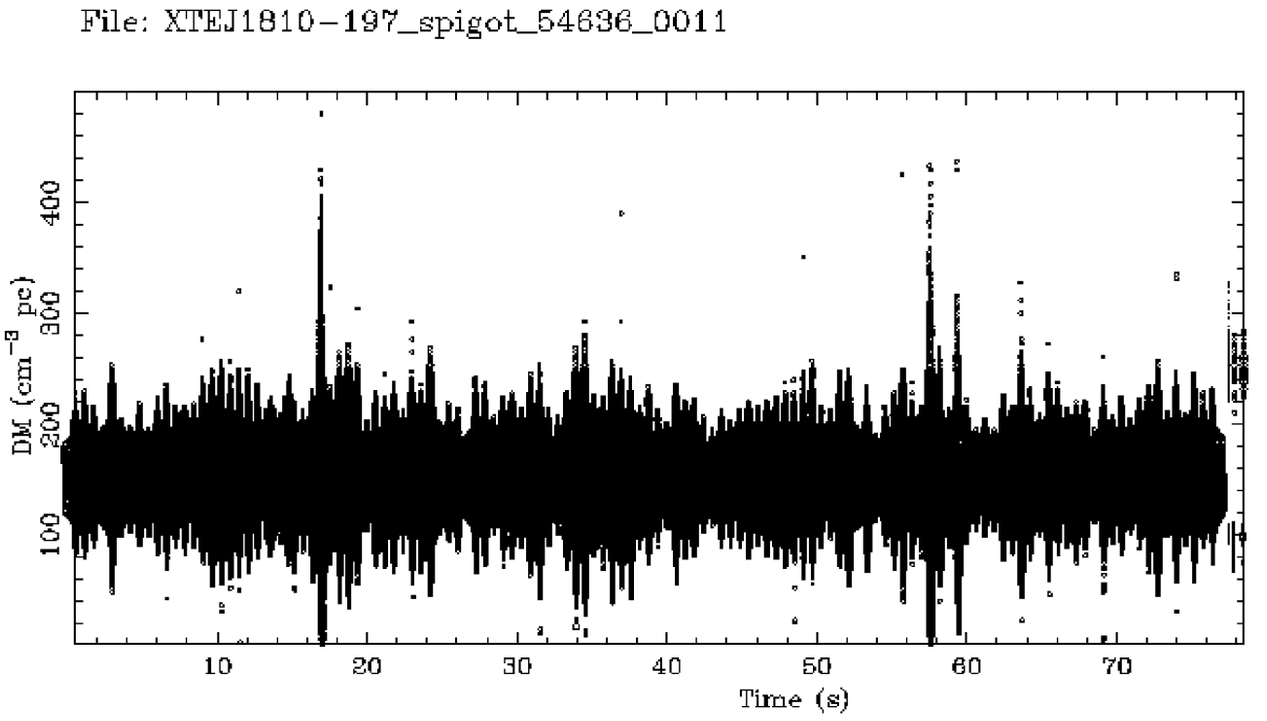

Figure 1: Single pulse plot for XTE1810-197 showing a bright detection of the magnetar at a DM of 177 pc/cm-3.

18:09:51.08

Source name	Right Ascension (J2000)	Declination (J2000)	P (s)	D (kpc)	DM (cm-3 pc)
4U 0142+61	01:46:22.4	+61:45:03.3	8.7	>2.5	70
1RXS J170849.0-400910	17:08:46.9	−40:08:52.4	11.0	8	700
SGR 1806-20	18:08:39.3	−20:24:39.9	7.6	14-17	1200
1E 1841-045	18:41:19.3	−04:56:11.2	11.8	6-8	530
AXP J1845-0258	18:44:54.7	−02:56:53.1	7.0	<20	1300
SGR 1900+14	19:07:14.3	+09:19:20.1	5.2	12-15	700
1E 2259+586	23:01:08.3	+58:52:44.5	7.0	3	90
SGR 0501+4516	05:01:6.78	+45:16:34.0	5.8	?	?
XTE J1810-197	18:09:51.08	-19:43:51.7	5.5	5	180

Table 1, above: Target list of magnetars plus the candidate AXP J1845−0258. Dispersion measures (DM) are estimates based on the distance constraints using the Cordes and Lazio (2001) electron density model.

So far, 6 epochs have been observed. SGR 0501+4516 is a newly discovered SGR observed with Swift and XMM-Newton in August 2008 (Israel et al. 2008). We were granted permission from the GBT scheduling committee to add this new source to our monitoring list in September and have so far obtained four epochs on this source. The first five epochs utilized the GBT setup with the S-band receiver centered at 2.1 GHz using the spigot backend in 800 MHz bandwidth with 1024 frequency channels and 16-bit recording mode. For the sixth epoch we have used a new backend, the Green Bank Ultimate Pulsar Instrument (GUPPI) in 800 MHz bandwidth with 512 frequency channels and 8-bit recording mode. The GUPPI data represent a substantial improvement over the original SPIGOT observations both in immunity to radio frequency interference and in size.

Results

All data collected thus far have now been processed using single pulse and periodicity searches. Single pulse searches are sensitive to any sporadic emission. They search for individual events that deviate from the mean. Periodicity searches make use of the Fast Folding Algorithm (Staelin

1969) to detect any coherent pulsations that might be present. While XTE1810-197 is routinely visible in these searches (Fig.1), all other sources in our list remain radio quiet or at least below the flux density thresholds of our searches. For periodic sources, assuming the pulse width is 10% of the pulse period, we reach a limiting S-band flux density of 30 μJy in each 30 minute observation, which is well below any expected radio emission from a magnetar. For individual bursts of width 10 ms, the threshold for a 10 σ detection is 40 mJy and is well within our sensitivity range.

Future of the Project

The project will likely run until the end of 2009. During this time, we will employ more sophisticated radio frequency interference (RFI) removal techniques and new algorithms for pulsar detection. This will allow us to provide better limits on the emission from the magnetar. At the end of this period, we will submit the complete results of this project to a refereed journal.

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DEVELOPMENT OF A RAPID ASSAY FOR PROLYL HYDROXYLASE IN MOUSE LUNG

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Abstract

The National Institute for Occupational Safety and Health is conducting research on the effects of respiratory exposure to carbon nanotubes. Exposure to some kinds of carbon nanotubes has been associated with a fibrogenic response in lungs that has negative effects on lung physiology and human health. A thorough understanding of the molecular events leading to fibrosis could offer prophylactic or therapeutic approaches to avoid the fibrosis. Several different enzymes are associated with fiber formation in the lung ,and one of interest is prolyl hydroxylase (PH-4). Current protocols for measuring PH-4 activity are expensive, cumbersome, and time-consuming. A rapid assay protocol would aid in our understanding of the regulation on the enzyme's activity. To prepare the tissue for assay, it was homogenized and then microsomes were prepared by differential centrifugation. Then, a surfactant was used to solubilize the protein, allowing substrate access. The incubation occurred in stoppered vials. The vials were placed in a 37 degree C water bath with shaking. A radioactive co-substrate for the reaction, 2-oxo[1-^{14}C]-glutarate, was incubated in the presence and absence of a synthetic peptide containing proline and the liberated $^{14}CO_2$ was captured. The reaction was terminated by adding pH 5 phosphate buffer to the reaction vial. Radioactivity was determined using liquid scintillation spectrometry. The peptide-dependent $^{14}CO_2$ captured was used to estimate enzyme activity. This assay has been determined to be linear with respect to enzyme concentration as well as incubation time. This is a useful method as it can be completed in a matter of hours and requires no previous preparation of tissue or substrate. This rapid assay will be used to assess PH-4 in mouse lung from mice exposed or not exposed to carbon nanotubes. PH-4 regulation, or a lack thereof, after nanotube exposure suggests the molecular pathway by which the fibrogenic response associated with carbon nanotube exposure is elicited.

Introduction

Carbon nanotubes are cylindrical carbon molecules with diameters on the order of nanometers and lengths on the order of micrometers (Chen et al. 2000). Carbon nanotubes are important because they have several novel and potentially useful properties making them desirable for many industrial and commercial applications. The manufacture of carbon nanotubes is increasing, and as such they are coming under increased toxicological scrutiny (Donaldson et al. 2006). Because of their size and physical properties, it is suspected that the toxicity of carbon nanotubes may be similar to that of asbestos (Prosie et al. 2008). Part of the physiological response elicited by asbestos fiber exposure is collagen deposition in the lung tissue (Wrzaszczyk and Owczarek 1996). PH-4 is an enzyme necessary for the production of collagen. It is a 2-oxoglutarate dioxygenase and catalyzes the reaction:

procollagen L-proline + 2-oxoglutarate + O_2 ⇔ procollagen trans-4-hydroxy-L-proline + succinate + CO_2 (Brenda enzyme database)

The enzyme decarboxylates 2-oxoglutarate. Also, one oxygen atom from the O_2 becomes incorporated into the succinate while the other oxygen atom from the O_2 becomes incorporated into the proline to generate 4-hydroxyproline. The enzyme is necessary for collagen production because the hydroxyl groups on the 4-hydroxyprolyl residues stabilize the triple helix of collagen under physiological conditions. The enzyme cannot interact with free proline or with proline occurring in just any amino acid sequence. Rather, it requires a minimum X-Pro-Gly triplet to interact with the proline. The intracellular location of PH-4 is within the cisternae of the rough endoplasmic reticulum. The enzyme requires Fe^{2+} and ascorbate, and maximal enzyme activity requires dithiothreitol, bovine serum albumin, and catalase (Kivirikko and Myllylo 1982).

The National Institute for Occupational Safety and Health (NIOSH) is currently conducting research on the effects of respiratory exposure to carbon nanotubes. Early results have demonstrated that some kinds of carbon nanotubes do elicit a fibrogenic response that leads to health problems (Lam et al. 2006; Shvedova et al. 2005). NIOSH is interested in determining the molecular pathway by which this fibrogenic response occurs. A change in the regulation of PH-4, or a lack thereof, after nanotube exposure suggests the molecular pathway by which the fibrogenic response occurs. For example, if PH-4 is upregulated it may indicate collagen deposition and thus a fibrogenic pathway similar to that of asbestos. Our role in NIOSH's larger study will be to determine if PH-4 regulation is altered in mouse lung after carbon nanotube exposure.

Several assays have been developed to measure the activity of PH-4. The assays use either radiolabeled biologically prepared substrate or a synthetic polypeptide substrate (as the source of procollagen-L-proline). The assays involving radiolabeled biologically prepared substrates

are the most sensitive, and in most reported cases only these methods can be used to accurately determine enzyme activity from crude tissue extracts (Kivirikko and Myllylo 1982). Unfortunately, these assays are expensive, cumbersome, and time-consuming. The assays using synthetic polypeptide substrates are less expensive and faster, but they have lower sensitivity and in most cases can only be used with partially purified enzyme.

For this particular project a quick, inexpensive assay that could be used with crude tissue extract was desired. By adapting previously published results (Kao et al. 1975; Kivirikko and Myllylo 1982), such an assay has been developed, and it will allow us to determine whether PH-4 regulation is altered after carbon nanotube exposure.

Methods and Calculations

Assay Overview

The components necessary to carry out the reaction (enzyme extract, peptide substrate, labeled 2-oxoglutarate, and cofactors) were added to a 3 mL reaction vial. The labeled 2-oxoglutarate was added last to begin the reaction. The reaction vial was then incubated at 37 degree C for 20 minutes. The reaction was ended by injecting pH 5 phosphate buffer into the reaction vial. The reaction vial was then shaken for 30 minutes to release the evolved CO_2. A base trap suspended in the reaction vial collected the evolved CO_2. This base trap was then placed in a liquid scintillation vial and counted.

Preparation of Assay Components

Crude enzyme extract was obtained from mouse lung. After the mice were sacrificed, their lungs were immediately harvested, weighed, and homogenized in enzyme buffer (Kao et al. 1975) (.2 M NaCl, .1 M glycine, 50μM DTT, .01M Tris-HCl, pH 7.8) using a Potter-Elvehjem tissue grinder and approximately 1mL buffer per gram of tissue. Depending on the particular experiment being done, between 1 and 5 mice were used. When multiple mice were used, their homogenized lungs were combined into one homogenate. The homogenate was then centrifuged in 1.5mL Eppendorf tubes at 10,000 x g for 20 minutes. The supernatant was then collected and put on ice. The pellet was resuspended in .5mL NaCl buffer and again centrifuged at 10,000 x g for 20 minutes. This supernatant was collected and added to the previously collected supernatant. The combined supernatant was then centrifuged at 37,000 x g for 30 minutes. The resulting pellet

was then collected (representing the microsomal fraction) and resuspended in the NaCl buffer. Triton X-100 (0.1 %) was added and the solution was placed on ice.

While centrifuging the enzyme extract, a "Master Mix" of enzyme cofactors and activators was prepared and kept on ice. This "Master Mix" consisted of 20mM ascorbic acid, 1mM $FeSO_4$, 1mM DTT, 20mg/mL bovine serum albumin, and 2 mg/mL catalase (Kivirikko and Myllylo 1982). The amount of Master Mix prepared was determined by the number of trials to be run (.333mL/trial).

The peptide substrate (Pro-Pro-Gly)10 • 9 H_2O was diluted to 1 mg/mL in distilled water and then heated at 100 degrees C for 10 minutes. After heating, the peptide was placed on ice. The amount of peptide prepared was determined by the number of trials to be run (.1mL/trial).

A solution of 2mM 2-oxoglutarate was prepared. The amount of 2-oxoglutarate prepared was determined by the number of trials to be run (.05mL/trial). Additionally, 20μL of 2-oxo-[1-^{14}C]glutarate (56.8mCi/mmol) was added to the 2-oxoglutarate solution. This solution was then placed on ice.

Trial Preparation

The reaction was carried out in 3 mL vials. These vials were kept on ice as the assay components were added. A 5mm boiling bead was placed in each reaction vial. Master Mix (.333mL) and enzyme extract (.3mL) were added to each reaction vial.

A base trap was prepared to capture the evolved CO_2. The base trap consisted of methyl cellusolve and ethanolamine in a 2:1 ratio. Base trap (.45mL) was added to a .5mL Eppendorf tube that was then suspended inside of the reaction vial.

Figure 1

Peptide solution (.1mL) was added to each treatment vial and (.1mL) distilled H_2O was added to each control vial.

In Figure 1, the 3mL reaction vial with .5mL Eppendorf tube suspended from the stopper. The Master Mix, 2-oxoglutarate, and peptide substrate are injected into the bottom of the reaction vial. The base trap is placed in the Eppendorf tube and collects the evolved CO_2.

Assay

Labeled 2-oxoglutarate (.05mL) was then added to each vial to start the reaction. Each vial was then immediately stoppered with the base trap suspended from a wire attached to the stopper. The vials were then incubated at 37 degrees C with shaking for 20 minutes. The reaction was ended in each vial by adding .5mL of pH 5 phosphate buffer (1 M KH_2PO_4) via a syringe inserted through the stopper.

The vials were then taken out of the water bath and shaken for 30 minutes at room temperature.

The Eppendorf tube containing the base trap was then added to a counting vial along with a scintillation cocktail and counted.

Calculation of Enzyme Activity

From the scintillation spectrometer we get a DPM (disintegrations per minute) value representing the labeled CO_2 collected in the base trap. This DPM value is converted to a CO_2 (and thus an enzyme activity) level by comparing it to the DPM from a labeled 2-oxoglutarate solution of known concentration. For enzyme specific activity, the DPM difference between the treatment trials and the control trials is used.

The calculation for enzyme specific activity is then:

(Treatment DPM – Control DPM) * ((moles 2-oxoglutarate)/(2-oxoglutarate vial counts)) = moles labeled CO_2

This result is divided by the amount of mouse tissue in each sample to get a unit for enzyme activity that has units of moles CO_2 evolved/g mouse tissue.

To optimize the assay in various respects the experiments shown below in table 1, table 2, and table 3 were performed. These experiments optimized the Master Mix volume, the size of the reaction vessel, and the rate of shaking during incubation. In each of these experiments, the procedure used was very close to the one just described.

Results

For all experimental results, the raw data came in the form of Disintegrations Per Minute (DPM). Enzyme specific DPM was obtained by taking the difference between trials run with the enzyme's peptide substrate ((Pro-Pro-Gly)10 • 9 H_2O) and trials run without it. This enzyme specific DPM can then be converted to enzyme activity with units of moles CO_2 evolved per gram tissue.

Table 4 and Figure 2 demonstrate the linearity of our assay with respect to differing enzyme concentration. Table 5 and Figure 3 demonstrate the linearity of our assay with respect to time.

Table 1 :Effect of Variations in Master Mix Volume

Master Mix Volume	.1666 mL peptide	.1666 mL no peptide	.333 mL peptide	.333 mL no peptide	.5 mL peptide	.5 mL no peptide
	1154.23	1011.11	1358.28	564.5	654.09	987.65
	1023.34	645.6	1221.34	1051.12	1768.8	795.26
	678.87	659.12	1477.24	908.43	1245.56	1654.23
	1409.23	605.72	1332.98	1013.13	1521.23	1256.67
	899.45	1432.3	1003.32	1066	1165.34	1340.48
	1890.21	1222.9	1060.43	998.08	432.23	543.7
	1722.39	983.34	1232.21	955.65	976.45	923.21
	1300.23	1450.08	1278.33	843.34	1343.75	459.47
Average	1259.74375	1001.27125	1245.51625	925.03125	1138.43125	995.08375
Enzyme specific DPM	258.4725		320.485		143.3475	
Standard Deviation	408.789206	345.7461947	155.2949729	163.3302627	440.4219828	406.7255518
T-Test	0.194224355		0.00126636		0.509929937	

This experiment was done using the 3mL reaction vial and shaking 110r/min. The Master Mix volume used in Kao et al. (1975) is .5mL. In this project smaller amounts of tissue are used, so it was decided to concentrate the Master Mix in an attempt to lower the reaction volume and obtain more precise results. The above data shows that lowering the Master Mix volume to .333mL increases the precision of the assay over the precision achieved when using Master Mix volume .5mL or .1666mL.

Table 2: Effect of Changing The Size of The Reaction Vessel

#(New) 3 mL reaction vial peptide	(New) 3 mL reaction vial no peptide	(Original) 25 mL Erlenmeyer peptide	(Original) 25 mL Erlenmeyer no peptide
539.6	343.6	358.4	187.4
625.6	383.5	542.8	333.2
635.7	349.1	486.4	535
541.7	358.1	677.9	301.2
411.4	443.6	827.5	491.9
604.9	445.1	482.3	565.1
401.7	348.4	664.4	558.2
622.5	377.7	861.4	866.1
446.6	331.7	709.3	543.1
584.2	354.1	456.67	
average	average	average	average
541.39	373.49	606.707	486.8
standard deviation			
90.57218668	40.32968165	166.9140732	196.3087364
Enzyme Specific DPM		Enzyme Specific DPM	
167.9		119.907	
ttest new		ttest old	
0.000152392		0.173208502	
Coefficient of variance	Coefficient of variance	Coefficient of variance	Coefficient of variance
16.72956403	10.79806197	27.5114797	40.32636328

This experiment was done using .5mL Master Mix and shaking 110r/min. Once again, due to the small amounts of tissue being used in this project, it was decided to lower the volume of the reaction vessel to try to cause more efficient mixing of the assay components and thus increase the precision of the assay. The above data shows that lowering the volume of the reaction vessel (from 25mL to 3mL) does increase the precision of the assay.

Table 3: Effect of Changing the Rate of Shaking During Incubation

shaking rate (r/ min)	50 peptide	50 no peptide	80 peptide	80 no peptide	110 peptide	110 no peptide
	1065.3	934.21	1078.12	956.65	1240.1	954.23
	1034.9	854.06	855.5	1190.22	1168.89	904.45
	876.54	1260.75	980.1	860.98	1300.4	654.15
	665.2	565.4	1184.46	544.4	988.89	1023.2
	1209.92	875.2	1353.3	990.02	1002.24	838.26
	1250	920.43	1109.23	1105.5	1037.72	906.5
Average	1016.976667	901.675	1093.451667	941.295	1123.04	880.1316667
Enzyme Specific DPM	115.3016667		152.1566667		242.9083333	
Standard Deviation	218.0149879	221.9883426	170.7379775	226.0588329	132.0077275	126.5438513
T-test	0.385384722		0.219793911		0.008684604	

This experiment was done using the 25mL Erlenmeyer flask and .5mL Master Mix. Increasing the rate of shaking during incubation more thoroughly mixes the assay components and increases the precision of the assay. Also, the enzyme specific DPM appears to increase with faster shaking. This is an added benefit, as higher enzyme specific DPM will make it easier to identify differences in enzyme specific DPM between individual mice.

Table 4: DPM With and Without Peptide Substrate and at Differing Enzyme Concentration

	[1] peptide	[1] no peptide	[.5] peptide	[.5] no peptide	[.25] peptide	[.25] no peptide
	1518.03	871.9	733.1	431.4	405.8	374.7
	2403.81	776.8	607.6	524.9	332.4	350.3
	1355.81	781.3	641	376.9	410.8	376.6
	1211.08	930	247.1	265.9	500.3	306.2
	1535.73	839.3	878.5	402.7	385	358.3
	952.4	1048.69	551.1	184.8	374.1	
average	1496.143333	874.665	609.7333333	364.4333333	401.4	353.22
Enzyme Specific DPM	621.4783333		245.3		48.18	
t-test	0.026679563		0.039117194		0.104464231	
standard deviation	494.4727028	102.8587116	211.3659449	121.516084	55.97174287	28.51853783

In this experiment, the assay was performed at standard enzyme concentration (represented by [1]) and also at one-half and one-fourth normal enzyme concentration ([.5] and [.25]). The t-tests compare the trials with the peptide substrate added for a given enzyme concentration to the trials without the peptide substrate added for that enzyme concentration.

In Figure 2: Graphical representation of the data from Table 4. Here the difference in DPM between Treatments (peptide) and Controls (no peptide) has been converted to enzyme activity with units of nanomoles CO2 evolved per minute.

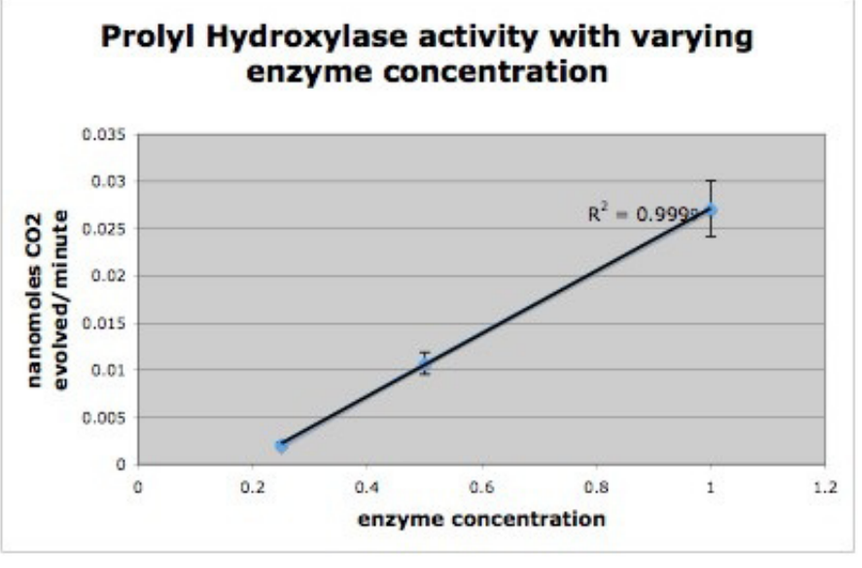

Figure 2

Table 5: DPM With and Without Peptide Substrate and with Respect to Time

	5 minutes peptide	5 minutes no peptide	20 minutes peptide	20 minutes no peptide	60 minutes peptide	60 minutes no peptide
	706.2	348.4	2087.89	1512.58	2780.51	1557.67
	668.3	289.6	2190.91	1775.27	3155	1985.94
	597.4	193.1	2066.19	1422.98	3681.09	1886.92
	670.1	406.65	1789.29	1418.44	2580.77	2325.58
	747.8	355.56	1983.23	1467.04	2637.9	2229.12
Average	677.96	318.662	2023.502	1519.262	2967.054	1997.046
T-test	0.003374733		0.13618652		0.005486779	
Enzyme specific DPM	359.298		504.24		970.008	
Standard Deviation	55.49804501	81.5446425	150.3916664	148.1107539	457.5826309	302.9419413

In this experiment the reaction was allowed to run for 5, 20, or 60 minutes.

Figure 3 is a Graphical representation of the data from Table 5. Here the difference in DPM between Treatments (peptide) and Controls (no peptide) has been converted to enzyme activity with units of nanomoles CO_2 evolved per gram of lung.

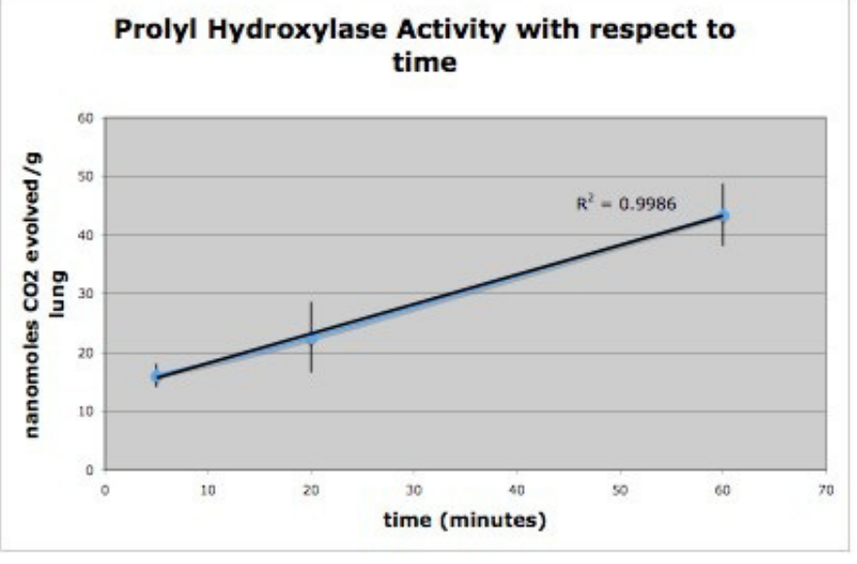

Figure 3

Discussion

The assay developed here is based on previously published results (Kao et al. 1975; Kivirikko and Myllylo 1982). In previous studies, researchers were concerned with demonstrating that a PH-4 assay that measures enzyme activity by following the release of $^{14}CO_2$ is reliable. In developing a PH-4 assay for use in the NIOSH project we

had the added requirement that the assay be able to be used to determine whether or not a statistical difference exists between the PH-4 activities of the lungs of individual mice. This meant that the assay needed to be able to give reliable enzyme activities using small amounts of tissue (a single mouse lung weighs ~.1g). In previously reported results working with small amounts of tissue was not a concern. For example, in Kao et al. (1975) 5g of tissue would typically be used per assay (the 5g value came from combining tissue from many subjects).

Having to work with a small amount of tissue means a couple things. Obviously, less tissue means less enzyme and thus less activity for us to measure. At low levels of activity it becomes difficult to obtain a statistically significant result. Further, because there is some inherent variability in the DPM for any given trial using this assay (note the large standard deviations in the Results section) it is necessary to run several treatment and control trials to get a sufficiently precise measurement of enzyme activity. Thus, our problem was that we needed to find a way to run several trials that produced DPM numbers high enough to be of use using a small amount of tissue.

The first step taken in this direction was to add an additional round of centrifugation at 10,000 x g in order to retain more of the microsomal fraction (PH-4's subcellular location is the endoplasmic reticulum). By next centrifuging the resulting supernatant at 37,000 x g and taking the pellet, the microsomal and mitochondrial fractions were separated. This is a useful step as 2-oxoglutarate is also a substrate for the oxoglutarate dehydrogenase complex of the citric acid cycle which occurs in the mitochondria. The result of this separation is that a larger percentage of the total activity during the incubation period is enzyme specific.

The surfactant Triton X-100 is used to solubilize PH-4 and allow it access to its peptide substrate. Rather than include the surfactant in the homogenization buffer as is done in the literature, we elected to add the surfactant after the microsomal fraction is collected. Adding the surfactant at this time reduces the chance that unwanted enzymes that will interfere with data collection will also be solubilized.

These changes in the centrifuging and solubilization procedure were necessary to obtain enzyme specific activity. That is, the difference between treatment and control trials was statistically insignificant before making these changes to the assay.

Again due to the small amount of tissue being used, we elected to further alter the assay as described in the literature by using a smaller amount of Master Mix solution, carrying out the reaction in a smaller vessel, and shaking the reaction vials more vigorously during incubation. The benefit of these changes is shown in Tables 1, 2, and 3, respectively. Using .333mL as the volume for the Master Mix resulted in the highest enzyme specific DPM and the lowest standard

deviation. The .333mL Master Mix also returned the lowest T-test result. Using the 3mL reaction vial instead of the 25mL Erlenmeyer flask to carry out the reaction lowered the standard deviation and returned a lower T-test value. Finally, shaking the reaction vial more vigorously during incubation (110r/min as opposed to 80 or 50) lowered the standard deviation and returned a lower T-test value.

This assay has been demonstrated to be linear with respect to both enzyme concentration (Table 4, Fig. 2) and time (Table 5, Fig. 3). These results are important as they demonstrate that the assay gives results that fit basic biochemical theory.

The assay is quick, easy, and inexpensive. It requires no previous preparation of tissue or substrate and can be completed from start to finish in a little over 5 hours. Reliable results have also been obtained breaking up the assay into two parts. After the last centrifugation step the enzyme extract can be placed on ice overnight and used the next day. This makes the assay even more convenient, as it creates two approximately three hour work sessions.

After much troubleshooting and tweaking, the assay is now at a point where it can be used for its intended purpose, determining whether or not carbon nanotube exposure alters PH-4 regulation in mouse lung.

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IMPLEMENTING PURSUIT OF PREY STRATEGIES IN AUTONOMOUS ROBOTS: A SYSTEMATIC RECONSTRUCTION OF BEHAVIOR AS FOUND IN TIGER BEETLES

Sawan Prabhu

Abstract

Vision is a key factor in detecting and pursuing prey in many animals, yet it can be constrained both by intrinsic limitations and the complexity of the visual environment. For example, tiger beetles are visual predators that frequently stop during prey pursuits, possibly because the limitations of their visual systems cause them to lose sight of their target when advancing towards it at high speeds. This problem may be compounded as the visual environment becomes more complex. To test these hypotheses, we used simulations with a video system to model pursuit strategies used by the beetle. We matched the properties of the robot video system to those of the tiger beetle visual system, and challenged it to pursue visual targets in a behavioral arena. Simulated robots successfully chased prey, producing pursuit trajectories different to those made by the beetles. In addition to furthering our understanding of biological vision, these experiments may suggest design principles for autonomous robots that may be required to navigate through unknown environments.

Introduction

Biomimetics is the application of biological methods and natural systems in imitation as designed by modern technology and engineering (Bar-Cohen 2006). Engineers believe that if they can completely understand the complexities of an organism, they should be able to recreate it using technology (Brooks 1990). Technology can be modeled after three different levels of biol-

ogy, (1) mimicking natural methods of manufacturing, (2) imitations of mechanisms found in nature, and (3) studying organizational principles from social behavior of organisms (Brooks 1990).

Tiger beetles are visual predators that chase down small insects using visual cues. Vision is a key factor to detect and pursue prey in many animals (Gilbert 1997). The behavioral strategies a predator uses to successfully capture prey are constrained by the limits of its visual system and the complexity of the visual environment. Tiger beetles stop when chasing prey, possibly because the limitations of their visual systems cause them to lose sight of their target when advancing towards it at high speeds (Gilbert 1997). Analyses of pursuit strategies of these beetles have been done by Gilbert (1997), who found that pursuit runs typically consist of bouts of running interspersed with periods of being stationary.

This brings us to the real question to be researched: Can we use robots as a tool to answer whether losing focus during pursuit characterizes the bouts of running and being still in tiger beetles? Mimicking these natural systems can help us understand prey pursuit methods. We can use these results to create a program similar to that used by tiger beetles for important robotic applications. Robots could be able to analyze a terrain and move forward in promising locations during search and rescue efforts to locate a given object (Brooks 1990).

It is hypothesized that in the simplest environments and with the best visual systems, the robot will perform the smoothest pursuit with least stops. As environmental complexity increases or visual systems become less capable, there should be an increased frequency in the start/stop behavior that the pursuer needs to reacquire the target.

Methods

This research was conducted with a series of simulations of beetle visual systems using WebotsTM 5, a program designed for fast prototyping and simulation of mobile robots (Cyberbotics 2008). Simulations were run using a virtual prototype, experimenting with what works and does not work. Virtual experiments included various stages that adjusted and observed varying levels of complexity. They were also used to determine capabilities of the visual system under different scenarios, and any effects that changes in the visual system may cause on the success rate of prey capture. The virtual tests were conducted using different complex environments with varied visual systems to see the most effective settings. Programming of the beetle robot and the prey remained the same for every run, except for those trials where the visual capabilities were altered. Visual capabilities were altered in the beetle robot by sampling the visual field

at different pixel resolutions ranging from full screen to every 2, 4, 8, 16, and 32 pixels. The robot visual system was comparable to that of a tiger beetle. The robot was programmed to scan the field and locate the prey. Once prey was in sight, the robot began to move towards the prey attempting to keep it in the center of the visual field. Anytime the target prey was not in sight, the robot turned clockwise until the prey was once again in view. Only one direction of turn was able to be programmed into the virtual robot. The robot was also programmed to stop every 0.75 seconds for a stop time of 0.05 seconds. The 0.75 second stops were used to mimic the average stops seen in Gilbert's results. This was the best way to program the robot to do what was seen in the beetle trials. Variable durations and inter-stop intervals were not able to be created due to limitations of Webot.

The playing field had a checkerboard base, tan walls, and a red sky. The checkerboard was composed of 10 by 10 boxes, each with an area of $36cm^2$. The robots were kept blue, and the robot was programmed to track blue objects (Cyberbotics 2008). The unusual look of the field was due to limits on the camera. During the stages of learning the program, it was discovered that green or any other color with a hint of blue would trigger the camera, causing the robot to chase the incorrect prey (Cyberbotics 2008). For this reason, the field was distinguished as not to confuse the robotic camera. Furthermore, it was not possible to get the program to get one robot to "catch" the other, so it was determined that the prey was caught when the camera robot ran through the prey robot. Since start and stop positions of the robot varied in each run, the results were compared by normalizing all runs to 100%. The translations and rotations were used to see overall changes between trials.

Results

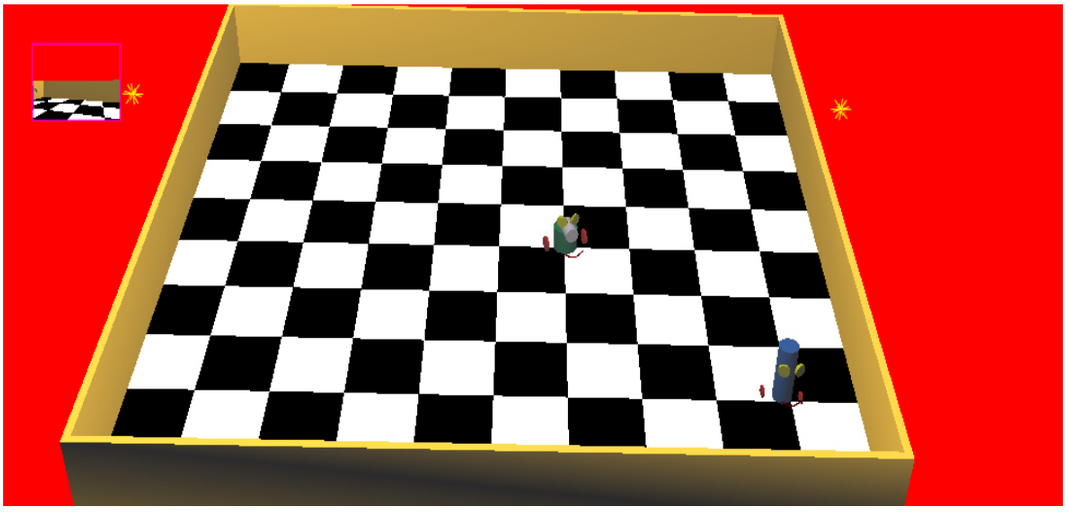

Figure 1, above: Screenshot from Webots of virtual field, with robot pursuing target prey. Robot pictured near center of field has the camera view, and is chasing the taller blue robot. Little square in corner depicts the view seen in the robot's camera (in this case, the prey is not in view).

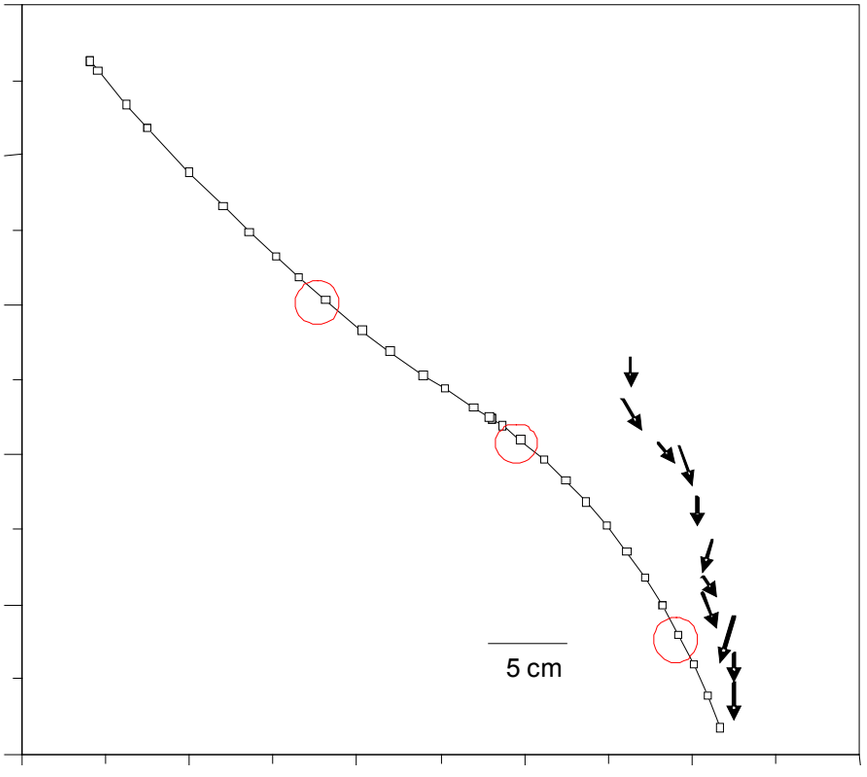

Figure 2, above: Trajectory of the robot during a pursuit run. Each square indicates the location of the robot at successive 0.1s intervals. Areas when the robot stopped are circled in red. The approximate path of the prey is depicted with black arrows.

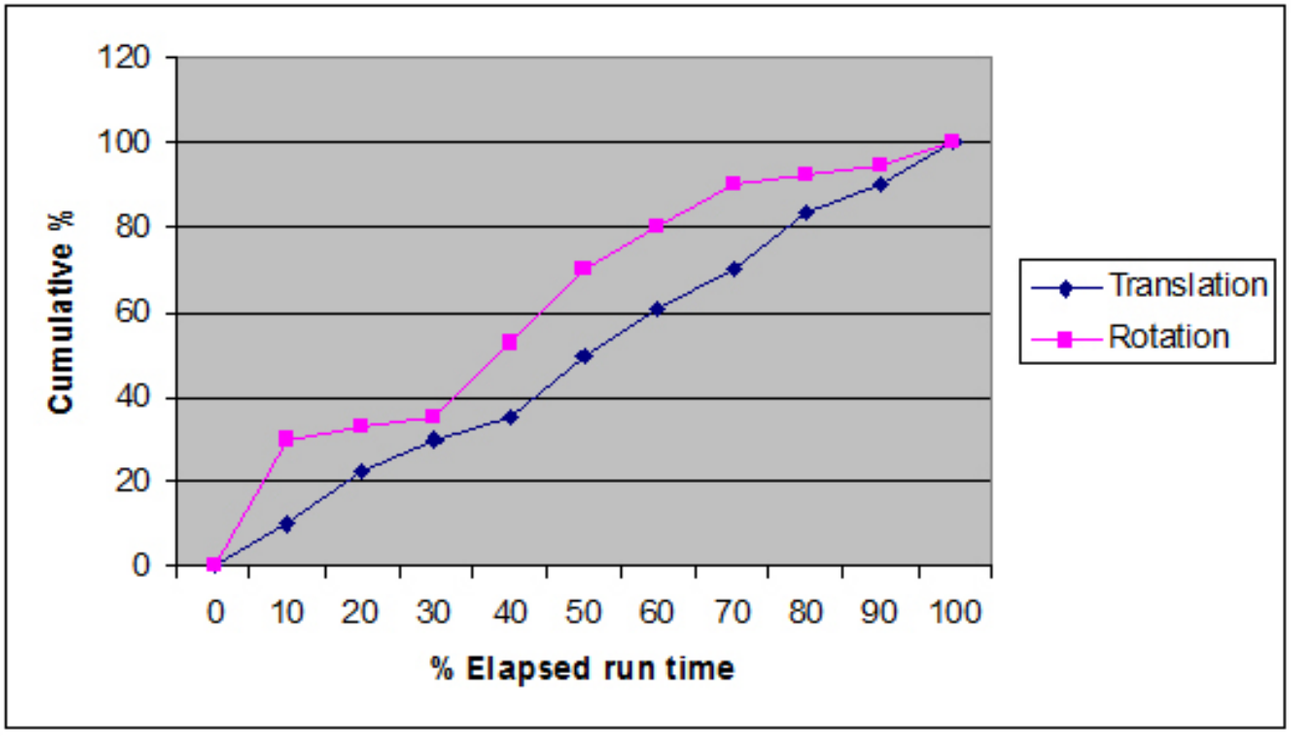

Figure 3: During each run, the Translation and Rotation were directly correlated. The mean cumulative distributions of the linear translation (blue line) and angular rotation (pink line) are seen above. The scaled percentages allow for comparison among the runs.

All runs during the experiment ended with a successful prey capture. A total of 37 successful prey capture runs were completed in a simulated 60 by 60cm playing field, with various robot visual capabilities (Fig. 1). The mean duration of the total runs were 2.53s ± 0.18s. In each segmented run, the portion between each stop and start typically lasted 0.754 ± 0.07s. On average, the robot stopped 3.4 ± 0.6 times during each run (as programmed in following pursuit strategies seen in Gilbert's paper) (Gilbert 1997).

Translation and rotation were also used to determine differences between runs. Translation references the distance traveled on the playing field by the robot. Rotation is the angular turning of the robot while tracking prey. Angular turning ranged from 1.44rad to 2.68rad, as the robot searched for the target prey when visual data were initially lost. Figure 2 depicts a representative example of the robot's trajectory, with a total of three stops. The data was the average of all the results. Figure 3 correlates the direct translation and rotation percentages during the duration of the runs. Figure 3 is a representation of the directional changes the robot underwent during a typical run. Overall, there was a greater increase in rotation at the beginning and mid sections of each run while translation increased steadily.

Discussion

Using Webot 5, a beetle prey pursuit trajectory was successfully reconstructed (Cyberbotics 2008). With each trial, it was apparent that the program did not follow the ideas as introduced by Gilbert's paper (Gilbert 1997). The programmed stops during pursuit allowed the robot to refocus and relocate the current position of the prey. However, these same programmed stops sometimes caused the robot to lose sight of the prey. Although we programmed stops into our robot to mimic the beetle, the results suggest that the stops hindered performance. Therefore, the beetle may not be stopping to refocus when chasing prey. Rather, they may be forced to stop due to other impairments in their visual system.

In Gilbert's paper, successful runs were determined by whether or not the beetle captured the prey (Gilbert 1997). The runs with the end product of a capture were significantly shorter than those of noncaptured runs (Gilbert 1997). However, the present research project focused on run lengths of the beetle robot with an end product always resulting in capture of the prey. In addition, the beetle starting position from the prey was significantly further than those in the real beetle trials (60cm vs. 30cm) (Gilbert 1997). This can help account for the increased time for the beetle robot to reach its prey. The average velocity of the virtual robot beetle was 300mm/s, whereas the beetles' velocities in Gilbert's paper averaged from 120.9 ± 17.1mm/s with a maximum at 538.7mm/s (Gilbert 1997).

The most important difference of this experiment deals with beetle rotation. In Gilbert's paper, the beetles do most of their turning in the first part of the run—60% of the turn is completed in the first 10% of the run (Gilbert 1997). The simulations in this experiment showed that the beetles continued to turn throughout the run to keep the prey in the visual field. The angular direction of the beetle robot with respect to prey during each chase varied; however, on average the beetle only rotated 1.26rad. The robot was programmed so that if the prey was not in sight, it would rotate clockwise until the target was reacquired. In most cases, it spotted the prey relatively quickly and kept the prey in the center of the visual field. Only during stops did the prey move out of the visual field. This depicts how stops hindered the robot from a quick prey capture.

Experiments using visual systems with decreased resolution showed no difference between runs (data not presented). When compared by starting the robot and prey from the same locations of full visual robot trials, it took exactly the same number of stops to reach the prey. With a larger field and decreased visual capability, one might predict a decrease in performance and an increased time to reach the prey. Since the playing field was limited in size, it could explain why it did not make a difference in these trial runs.

Segmented runs, the times between each stop and go, were 0.75s while those in Gilbert's paper were 0.1639s (Gilbert 1997). The 0.75s stops for our robot were programmed in to test stopping function, using a consistent stop time as seen in the beetles. Often times the robot was able to successfully track the prey, while other times, the stop only caused the robot to lose sight of the target. Stops seemed to hinder the chase rather than help; the stops extended the time from first sight to final catch. Although stops increased prey capture times in the robot, stops may be unavoidable in beetles. In future studies, changing field sizes and robot stop times and frequency can be a definite possibility to further understand the basis behind the beetle stops and trajectory towards prey (Brooks 1990). As a basic test of function in robotics, this method was successful for the robotic beetle to catch its prey.

Studies such as these are important since their applications are numerous. Learning and applying autonomous modes mimicking natural systems of tiger beetles to robots can increase robotic capabilities (Bar-Cohen 2006). Giving the robot the ability to follow and make its own decisions can increase ability of robots to seek a given object (Brooks 1990). This autonomous ability could be applied to search and rescue efforts, whether it be in space or global situations (Brooks 1990). After the World Trade Center crisis, robots were sent into the rubble to search for remaining survivors and important data on safety zones, yet their efforts failed (Carlson et al. 2004). Sources of the failure led primarily to control systems as robots were teleoperated and the unexpected environmental complexities and limitations of user interface sensors caused the robots to become stuck or otherwise unusable (Carlson et al. 2004). If these same robots were capable of analyzing the terrain and moving forward on their own accord, the search efforts could have provided more useful information. The simple function of allowing the robot to stop and "rethink" its path allowed it to successfully capture prey every run.

Conclusion

The tiger beetle's pursuit strategies can be mimicked in biomimetic robotic programs to determine how the tiger beetles chase down their prey. An interesting thing with these beetles is that they stop during pursuit, which is believed to allow the beetle to reposition and retarget, as they cannot process visuals during the run (Gilbert 1997). Overall, Webot 5 was an efficient program for recreating a tiger beetle's field (Cyberbotics 2008). As seen in this research project, the stops were detrimental to the robot when chasing prey. Learning more about stopping processes can contribute possible ideas for important robotic applications like search and rescue efforts in which the robot could analyze the terrain and move only towards a promising location (Brooks 1990). Allowing the robot to recheck its function and make decisions, it gives the robot greater probability towards finding a given object, though it can extend the search time (Brooks 1990).

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BIOMIMETIC PROMOTION AND INHIBITION OF CRYSTAL GROWTH IN CALCIUM CARBONATE

Adam M. Sadowski and R. Lloyd Carroll

Abstract

Living organisms have evolved effective mechanisms to control the growth of inorganic crystalline materials as structural elements. Previous research has shown that proteins rich in aspartic acid play a pivotal role in driving crystalline orientation, structure, and morphology of calcium carbonate biominerals in the formation of shells in marine bivalves (mussels, clams, abalone). In our research, we examine the effect of aspartic acid on the growth of calcium carbonate by a novel vapor diffusion-based growth technique. The vapor diffusion approach uses a gas-permeable membrane as a barrier to control the physical location of crystal growth. In this way, we are able to directly observe the crystal nucleation and growth using optical microscopy and record changes in growth rates and crystal orientation as we add peptide or polyelectrolyte-based modifiers to the growing crystals. Raman spectroscopy was employed to characterize the resulting crystals and provide insight into the actions of the growth modifiers. Our work is directed towards understanding how molecular modifiers interact with inorganic materials. Developing controls for the growth of calcium carbonate materials could have impacts in many industries which rely on the materials (including pharmaceutical development, household products, and paper, rubber, and paint manufacturing).

Introduction

Biological organisms have developed specialized techniques to incorporate inorganic and organic components into well structured hybridized materials (Ludwigs et al. 2006; Naka and Chujo 2001). This is observed with some biological organisms that produce protective structures that have been shown to increase in strength up to three thousand times when formed as

biominerals complexed with proteins, as compared to the same materials produced in purely mineralized form (Naka and Chuja 2001). This is a commonly found motif in mineralized frameworks found in organisms such as mollusks and other organisms (Addadi et al. 2006; Orme et al. 2001; Sarikaya et al. 2003; Sugawara et al. 2003). The formation of these hybrid materials in living organisms is part of a process called biomineralization (Miura et al. 2005). Recently, efforts to harness such processes to produce inorganic materials has lead to the development of the field known as biomimetics. This approach seeks to emulate approaches that biological organisms employ but apply it to synthetic materials for potential use in a wide range of applications, such as semiconductor devices, pharmaceuticals, and household products (Boncheva et al. 2002).

A common material found in many organisms as a biomineral is calcium carbonate ($CaCO_3$). This compound is found in the eggshells of birds, as well as in teeth and shells of mollusks (Thompson et al. 2000). Calcium carbonate exists in three typical structures in nature: vaterite (generally spherical), aragonite (spicules), and calcite (rhombohedra), in order of increasing thermodynamic stability (Sarikaya et al. 2003). Although calcite has the lowest energy structure, the presence of other polymorphs depends on nucleation and other kinetic factors.

The investigation into CaCO3 structure and formation in biomineralization has been extensive. Kim et al. (2006) incorporated proteins AP7-N, AP24-N, and n16-N, rich in aspartic acid and all found as constituents of abalone nacre and oyster, to promote elongation and inhibition of different surface region domains in calcite (Kim et al. 2006). Butler et al. (2006) investigated the incorporation of carboxylic acids and sulfated polysaccharides into calcite and found that carboxylic acid promoted formation of stacked rosettes, while sulfated polysaccharides inhibited calcite crystallization (Butler et al. 2006). Some studies have investigated the control of surface modification of calcite by the use of self-assembled monolayers on gold, while others have investigated growth control by titration and filtration through glass wool to monitor orientation in calcium carbonate (Addadi and Weiner 1985; Lee et al. 2001).

Our research utilizes similar approaches but mimics the membrane scaffolding and integration of solution modifiers of invertebrate systems. This paper examines a novel approach for crystal modification at the gas-liquid-solid interface via a semi-permeable polymer membrane composed of polydimethylsiloxane (PDMS). This is a novel application of PDMS as a gas permeable membrane to investigate the growth modification of calcium carbonate in solution. Our biomimetic methods have successfully demonstrated that in the presence of L-aspartic acid vaterite is the dominant form and that this crystal is stable with time. Previous studies have found that vaterite will thermodynamically reorganize into calcite through an amorphous $CaCO_3$ phase (Vagenas et al. 2003). In the absence of solution modifiers, calcite is the dominant polymorph produced. One goal of this research is to understand how the amino acid interacts with the calcium carbonate and drives the nucleation and growth of specific polymorphs.

Experimental Section

Our experimental design was implemented to understand the nucleation and synthesis of the generated crystals. To develop a system that mimicked biological activity, we employed a gas permeable membrane formed from PDMS. This was made by mixing a 1:10 ratio of precursor polymer to curing reagent (Dow Coming 187). The PDMS membrane was formed in Petri-dishes of two different thicknesses, a thin membrane of approximately 57μm and a thick membrane of approximately 1cm thick. The thick PDMS was cut into 0.5 x 1.0inch blocks. Two holes were then punched into the block with a metal rod generating a 0.3cm in diameter hole. The thin membrane was cut into small 0.6 x 0.6cm squares which were placed over the holes. The membranes were cleaned with liquid soap and rinsed extensively in de-ionized water and placed on Corning cover glass slips of 24mm x 50mm (Fig. 1).

This experiment utilized two amino acids: D and L aspartic acid. Solutions of 20 mM $CaCl_2$ and 1mM aspartic acid (Fluka), in 50 μl increments were used to exhibit $CaCO_3$ formation. Calcium carbonate crystals were generated using a slow nucleation process. We used ammonium carbonate (Fisher), which decomposes to give off CO_2 and NH_3 gas. To induce vaterite formation 1mM D or L-aspartic acid with 20mM $CaCl_2$ solutions were made. The following equations detail calcium carbonate crystal growth:

A. $(NH_4)_2CO_3 \Rightarrow NH_3g + H^2CO_3$
B. $H_2CO_3 \Rightarrow H_2O + CO_2g$
C. $CaCl_2 \Rightarrow Ca^{+2} + Cl^-$
D. $CO2g + H_2O \Rightarrow H_2CO_3 \Rightarrow H+ + CO_3^{2-}$
E. $CO_3^{2-} + Ca^{+2} \Rightarrow CaCO_3$

As the $(NH_4)_2CO_3$ decomposes into carbon dioxide and ammonia gas, the CO_2 will diffuse from the external environment and into the thin membrane. The CO_2 is then converted into bicarbonate when reacted with water, which then decomposes into aqueous carbonate ion. The carbonate ion binds to the calcium ion in solution and nucleates calcium carbonate crystals. Note that reactions A and B take place outside the thick PDMS segment, while C, D, and E take place inside the thick PDMS segment (Fig. 1, Fig. 2).

The setup designed in Figure 1 was placed into a 100mm diameter Wheaton desiccator. The pH of the $CaCl_2$ solution was found to be 10.3 and the pH in the desiccator environment was 8.5. Ammonium carbonate, crushed and weighed at 0.7g was placed into a small cap on the bottom of the desiccator. This allowed the slow diffusion of CO_2 gas to penetrate the thin membrane. Since CO_2 diffuses through the PDMS membrane, it will pass through the thin 57μm thick membrane before diffusing through the 1cm monolith. Thus nucleation occurs on the thin membrane (Fig. 2).

Growth Chamber

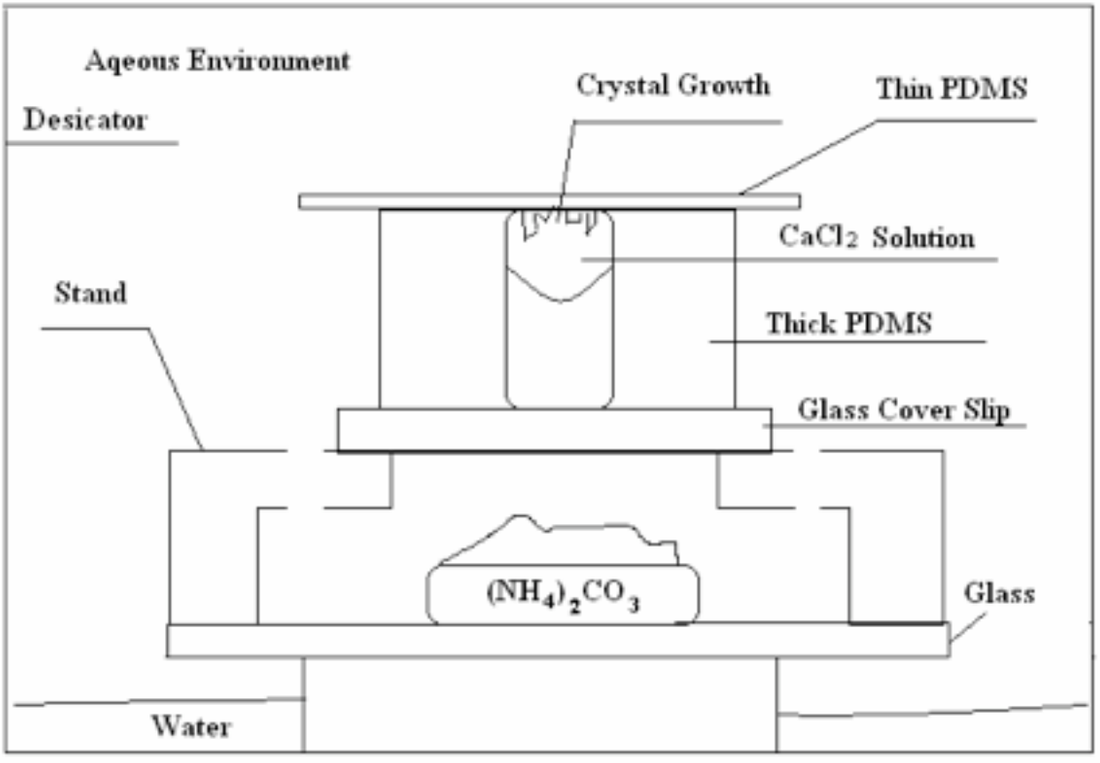

Figure 1: Experimental set up for production of calcite crystals.

Reactions Occurring in PDMS Membranes

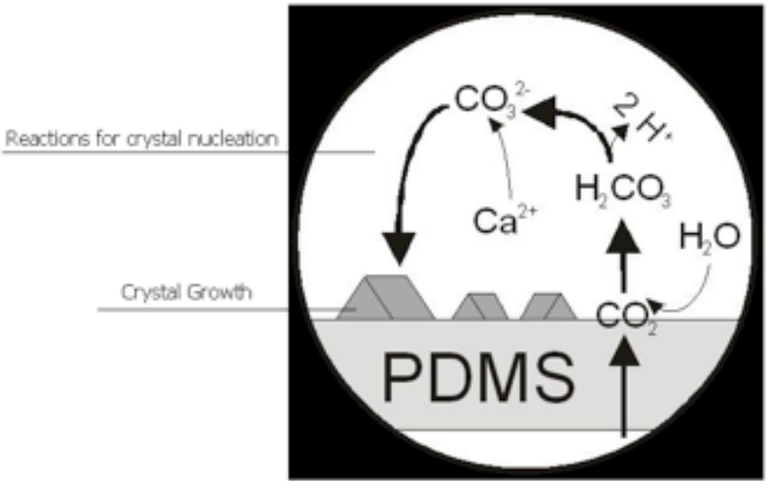

Figure 2, above: Illustrates how the ions of Ca^{+2} and CO_3^{2-} combine to form calcium carbonate crystals.

Calcium carbonate crystals were allowed to grow for 24 hours. The 57μm PDMS membrane bearing crystals was removed, briefly washed in de-ionized water, dried in a stream of filtered air, and stored for further investigation. Light microscopy and Raman anaylsis were used to identify specific polymorphs of $CaCO_3$.

Results/Discussion

Calcite and vaterite may be distinguished by shape, as they are characteristically either rhombohedral or spherical, respectively. To identify specific polymorphs of calcium carbonate, inspection by optical microscopy and identification by Raman microscopy and spectroscopy were used. To ensure that the crystals forming were calcium carbonate, we used simple polarization microscopy. $CaCO_3$ is a birefrigent material. Thus, by using crossed polarizers at 90 degrees, we were able to distinguish between precipitated starting material, $CaCl_2$ (which is not birefringent), and the material of interest, $CaCO_3$.

Raman spectroscopy revealed characteristic peaks for each polymorph crystal examined. This quantitative analysis is used to strictly identify which polymorph is being formed. This was conducted by selecting crystals through optical microscopy then collecting Raman spectra of specific crystals, which allowed us to characterize and identify individual crystals on the PDMS membrane. Raman spectroscopy was employed to demonstrate quantitative analysis of distinct peaks for each polymorph, calcite at 154, 280 and 711cm^{-1} and vaterite at 288, 301, and 750 cm^{-1} (Fig. 3) (Kontoyannis and Vagenas 2000). The Raman spectra were also used for categorizing data since the less stable vaterite has been observed to thermodynamically morph to the more stable calcite morphology over time (Vagenas et al. 2003).

We were also interested in the mechanism between the amino acid aspartic acid and calcium chloride to induce the specific crystal orientation of vaterite. Based on electrostatic charges, it is thought that the calcium ions on the crystal during growth are interacting with the negatively charged acidic carboxyl groups. This would cause an impeding interaction of ions to form on the crystal faces. Therefore the crystal cannot grow in a certain direction. This has been seen with similar acidic polypeptides, where the control of crystal faces has been hindered in the presence of acidic peptides (Volkmer et al. 2004). Much about this interaction is still unknown; however some potential explanations can be suggested.

One mechanism behind this electrostatic relationship suggests that the Ca^{+2} from $CaCl_2$ will interact with the COO^- from aspartic acid and thereby induce crystal modeling, causing adsorption of layers of amino acid on the crystal faces and lowering the surface energy, which

should induce a change in equilibrium (Teng et al. 1998). The binding of such ions is not random and has been shown to be part of an ordered array of calcium and carboxyl groups (Addadi et al. 1986). According to Gibbs free energy considerations, stable vaterite can be favored in the formation of supersaturated micro-environments in which the concentration of carboxyl groups increases with a corresponding increase in the electrostatic interactions between Ca^{+2} and COO^{-} groups on the aspartic acid (Tong et al. 2004).

Evidence for such an interaction can be seen from light microscopy growing crystals (Fig. 4). Some of the faces of crystal grown after several hours are clearly seen to be inhibited after the addition of aspartic acid. Some faces of the calcite crystals appear to be degenerate and become rounded at the edges after additions of aspartic acid, compared to the pictures before the acid additions (Fig. 4). This appearance indicates interactions between the calcium (on the growing calcite surface) and carboxylate funtional groups on the amino acid, which seem to be impeding growth on the edges of the calcite crystals. Similar affects have been observed in other studies (Teng et al. 1998).

Raman Spectra

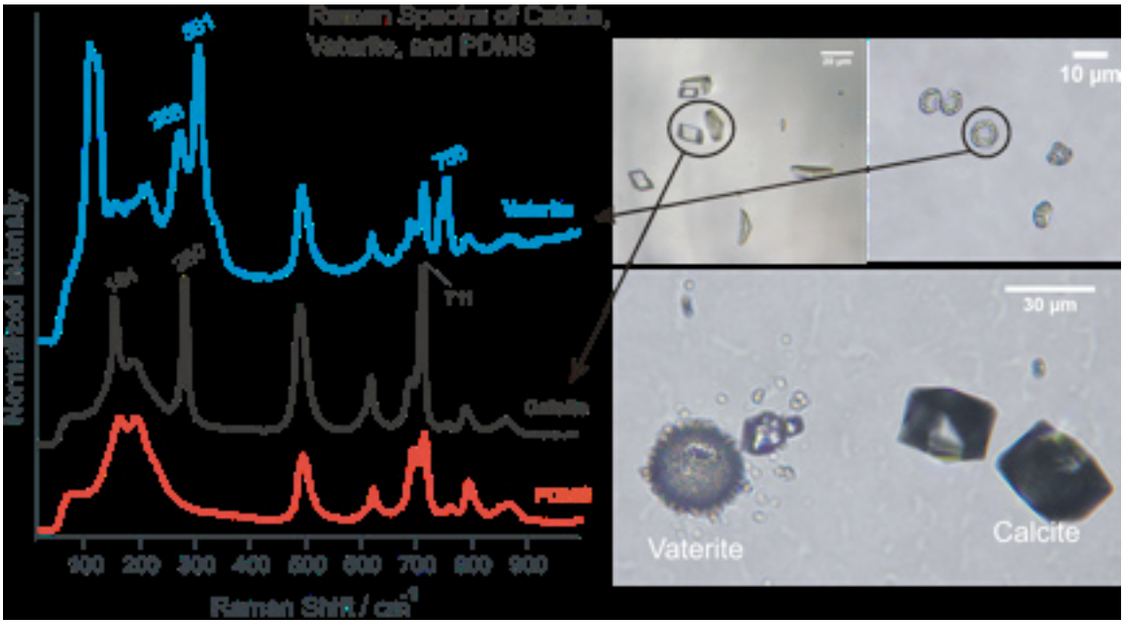

Figure 3: Raman spectra of calcite, vaterite, and PDMS. (a) Illustrates calcite crystals grown from $CaCl_2$. (b) Illustrates vaterite crystals grown from CaCl2 with L-aspartic acid. (c) Illustrates structures of calcite and vaterite crystals grown on the same PDMS membrane. The raman spectra to the left shows distinct peaks specific to crystalline calcium carbonate polymorphs, vaterite and calite, as well as those for the PDMS substrate.

Calcite Modification

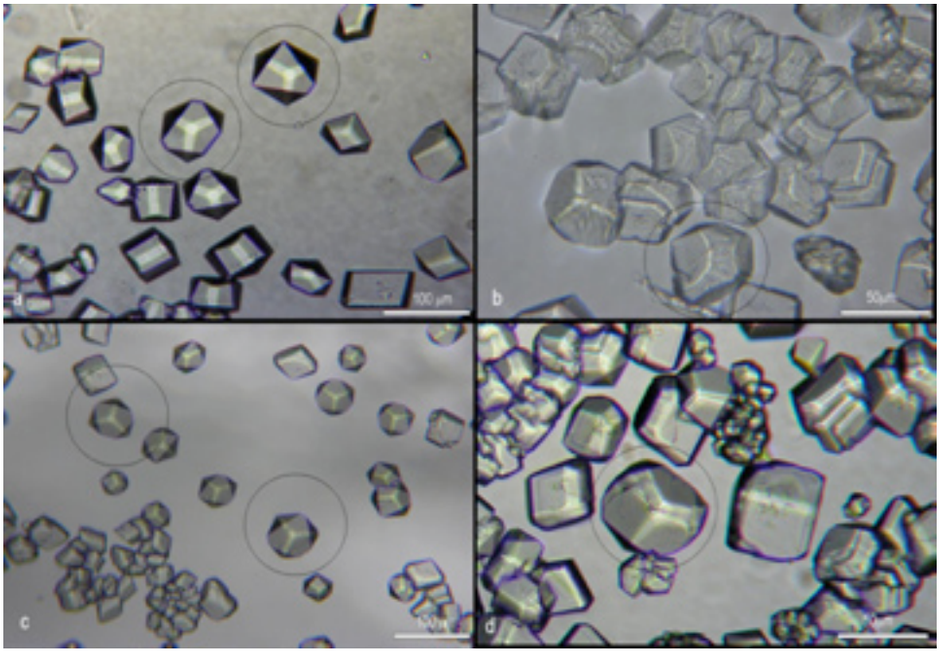

Figure 4: (a) Optical micrograph showing calcite growth before addition of L-aspartic acid. (b) Higher magnification micrograph of calcite growth after L-aspartic acid addition. (c) Optical micrograph of calcite growth before D-aspartic acid addition. (d) Higher magnification micrograph of calcite growth after the addition of D-aspartic acid.

Calcite was successfully modified using synthetic amino acids of D and L aspartic acid. More data is needed to understand these control effects and other modifiers which can be used to direct nucleation of calcite structure and orientation. We are currently investigating the use of optical and scanning electron microscopic examination to assign crystallographic orientations to understand which crystal faces are being selectively inhibited by amino acid interactions.

This research has many potential benefits. Understanding the mechanisms of biomimetic biomineralization gives insight into the fundamental approaches taken by living systems. Developing controls for the growth of calcium carbonate materials could have considerable effects on wide ranging industrial applications such as pharmaceuticals, cleaning products, and papermaking, which use calcium carbonate extensively. We also anticipate broader impacts in potential applications of non-biogenic material growth (such as metals and semiconductors) and applications in nanotechnology.

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